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# BARLEY VS. WHEAT AS THE BASAL FEED IN THE BACON HOG RATION[1]

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Previous trials in this series of feeding tests designed to evaluate Canadian Western grains and elucidate the best methods of using them for bacon hog production have demonstrated that, unlike barley, wheat when used as the sole basal feed of the ration may be expected to cause a lowered carcass excellence sufficient to materially reduce the cash returns from the hogs. It seems probable however, that wheat might be incorporated in mixtures with barley with satisfactory results. The limit to which it might be so used is at present unknown.

There was also the possibility that the best use might be made of wheat by restricting it to a part of the feeding period. Whether this should be for the finishing period to make use of the high energy value of the wheat, or for the growing period to capitalize on its vitamin B content in stimulating large feed intake and early growth rate is likewise unknown.

It was to obtain information on these questions that the hereinafter reported feeding trials were carried out.

## EXPERIMENTAL PROCEDURE

Sixty June-born Yorkshire pigs averaging 44 lb. were allotted at random to 10 feeding groups of 6 pigs each. A second replicate of 60 October-born pigs was started the following December, so that in all 120 pigs are represented in the data herein reported. Within each feeding group in each replicate, equal numbers of male and female pigs were used. All pigs were individually penned and fed.

On the weekly weigh day on which the pigs individually reached about 110 lb. in weight they were changed from the starting "A" ration to the finishing "B" ration. These rations differed only in that the protein-mineral supplement made up 15% of the "A" rations; and 10% in the "B" mixtures.

The protein-mineral supplement consisted of:

40% Meat meal—(55% protein).
25% Linseed oil meal.
15% Fish meal.
10% Feeding bone meal.
5% Ground limestone.
5% Fine salt.

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To each 100 lb. of this supplement, 0.2 grams potassium iodide was added when mixed.

The final rations fed to the several experimental groups were prepared by combining the above supplement with the following basal feeds or feed mixtures.

| *Lot* | *Basal Feed or Feed Mixture* |
|---|---|
| I | Wheat 50% + Oats 50% |
| II | Wheat 100% (No. 4 Northern) |
| III | Wheat 75% + Barley 25% |
| IV | Wheat 50% + Barley 50% |
| V | Wheat 25% + Barley 75% |
| VI | Barley 100% (No. 2 C.W.) |
| VII | Barley to 100 lb. weight followed by Wheat to market weight. |
| VIII | Barley to 150 lb. weight followed by Wheat to market weight. |
| IX | Wheat to 100 lb. weight followed by Barley to market weight. |
| X | Wheat to 150 lb. weight followed by Barley to market weight. |

All pigs until they weighed 110 lb. received daily 15 cc. of feeding fish oil of 2000 A and 400 D potency. The starting (A) rations were fed three times and the (B) rations twice daily in amounts limited by the pigs' appetites. Actual feeding was done by placing the allowance of meal mixture for each pig in his feeding trough and pouring over it about three times its weight of water.

As the pigs individually reached market weight they were slaughtered and the carcasses examined by Dominion Government Hog Graders according to the scheme of scoring employed for pigs on Advanced Registry test.

The design of the trial made possible a statistical analysis of the variance of the items of data according to the following scheme.

| Source of Variance | Degrees of Freedom | |
|---|---|---|
| All causes (120 pigs) | | 119 |
| Between 40 sub-groups | | 39 |
| Between 2 sexes | 1 | |
| Between 2 seasons | 1 | |
| Between 10 lots | 9 | |
| Interaction (total) | 28 | |
| Sex × season | 1 | |
| Lot × sex | 9 | |
| Lot × sex | 9 | |
| Lot × sex × season | 9 | |
| Within sub-groups (error) | | 80 |

## RESULTS

A summary of the general means of the important items of data recorded is given in Table 1 and will serve as a description of the typical pig in this test.

TABLE 1.—GENERAL MEANS OF WEIGHTS, GAINS AND FEED INTAKE

| Item | | Mean | Standard Deviation |
|---|---|---|---|
| | | lb. | lb. |
| Initial wt. | | 43.6 | 10.9 |
| Shipping wt. | | | |
| Males | | 200.0 | 5.64 |
| Females | | 202.0 | 5.76 |
| All | | 201.0 | 5.7 |
| Gain | | | |
| A ration | Males | 1.30 | 0.13 |
| | Females | 1.19 | 0.16 |
| B ration | Males | 1.70 | 0.23 |
| | Females | 1.51 | 0.20 |
| Total period | Males | 1.50 | 0.13 |
| | Females | 1.36 | 0.16 |
| | All | 1.43 | 0.15 |
| Daily feed total period, all pigs | | 5.6 | 0.45 |

Other than for the fact that pigs averaged 44 lb. in weight at the start of these tests and that males and females were marketed at the same final weights the only matter of importance brought out in Table 1 is the highly significant difference in rates of gain between the sexes. This was evident from the first. Male pigs have gained from 10 to 15% faster, the greatest difference being during the fattening period.

This same fact may be shown in length of feeding periods needed to get pigs to market weight. Between the May-born and January-born groups there was no appreciable difference (111 vs. 113 days); but between males and females the difference was two full weeks (105 vs. 119 days). This was a greater difference than was found between any of the ration groups and illustrates the necessity for a consideration of sex difference in all pig feeding trials in which gain is one of the criteria of the effect of the experimental treatment.

It may also be pointed out that the females were slightly more variable in gains than the males. This was not enough to be a matter of importance in these tests, however.

In Table 2 the average data for the weights and gains of the pigs are shown according to the ration comparisons made. In so far as the live pig data are concerned, rate of gain and efficiency of ration in producing gain are the two most important items to be considered. With respect to

TABLE 2.—MEAN WEIGHTS, GAINS AND FEED INTAKE OF PIGS

| Items | All pigs | I Wheat 50 + Oats 50 | II Wheat 100 | III Wheat 75 + Barley 25 | IV Wheat 50 + Barley 50 | V Wheat 25 + Barley 75 | VI Barley 100 | VII Barley to 100 lbs. | VIII Barley to 150 lbs. | IX Wheat to 100 lbs. | X Wheat to 150 lbs. | Necessary difference between lot means |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Initial weights | 43.6 | 44 | 45 | 43 | 45 | 44 | 44 | 44 | 42 | 44 | 43 | 2.0 |
| Days fed | 112 | 107 | 111 | 109 | 109 | 112 | 115 | 114 | 120 | 108 | 114 | 9.0 |
| Final weights | 201 | 202 | 201 | 201 | 200 | 201 | 198 | 204 | 202 | 201 | 200 | 5.0 |
| Daily feed | | | | | | | | | | | | |
| A period | 4.2 | 4.5 | 4.2 | 4.1 | 4.1 | 4.1 | 4.2 | 4.2 | 4.1 | 4.2 | 4.0 | 0.32 |
| B period | 7.0 | 7.2 | 6.7 | 6.8 | 7.2 | 7.2 | 7.0 | 6.9 | 6.6 | 7.3 | 7.1 | 0.55 |
| Total period | 5.6 | 5.9 | 5.5 | 5.5 | 5.7 | 5.6 | 5.6 | 5.6 | 5.3 | 5.8 | 5.6 | 0.37 |
| Daily gains | | | | | | | | | | | | |
| A period | 1.24 | 1.35 | 1.28 | 1.29 | 1.26 | 1.20 | 1.20 | 1.18 | 1.16 | 1.31 | 1.21 | 0.12 |
| B period | 1.61 | 1.65 | 1.59 | 1.68 | 1.65 | 1.65 | 1.55 | 1.59 | 1.55 | 1.60 | 1.58 | 0.18 |
| Total period | 1.43 | 1.51 | 1.43 | 1.47 | 1.46 | 1.41 | 1.37 | 1.41 | 1.35 | 1.45 | 1.39 | 0.12 |
| Gains (total period) adjusted to average feed | 1.43 | 1.44 | 1.47 | 1.51 | 1.44 | 1.41 | 1.37 | 1.43 | 1.41 | 1.41 | 1.40 | 0.09 |

gain it is interesting to note that if the lots are ranked in order of their observed gains over the total period the first three were fed rations having 50% or 75% wheat.

It seems evident that any penalty in rate of gain due to barley is to be found chiefly during the growing period. Pigs started on wheat (Lots IX and X) made as rapid gains when finished on barley as pigs finishing on wheat after a slow start on barley (Lots VII and VIII). These differences in gains at the start of the feeding do not appear to be due to lack of palatability of the barley if the feed intake on the "A" ration is indicative. Indeed, excepting for the oats-wheat ration there is no evidence of a difference in feed intake traceable to kind of diet. The oats-wheat combination appeared to be particularly well liked by the pigs, though the efficiency of the ration was no better than the comparable barley-wheat mixture.

When the gains are adjusted (by regression) to those expected had all lots eaten the same (average) amounts of their respective rations it appears in general that ration efficiency declines as barley becomes more than 50% of the basal mixture; or as pigs are slowed up by starting on straight barley (then finished on wheat); or are finished on barley after starting on wheat. In terms of feeding period these differences are of the order of a week in time. The slowest group was in market at 27 weeks of age. Hence for practical purposes it might be considered that there was little difference between any of these 10 ration mixtures. This is in agreement with previous tests in this series, viz., that on the basis solely of gains and feed efficiency barley and wheat appear to be excellent hog feeds. The differences between them are much more apparent in their effects on the carcasses produced.

As already noted, the pigs of this trial were slaughtered and the carcasses examined by Dominion Hog Graders according to the plan followed for hogs of the Advanced Registry tests. Carcass grade is the rail grade on which the bonus payments are based. Carcass score is the basis of the qualification of sows in the Advanced Registry. Both are measures of carcass excellence for bacon production. Since they are not based on identical measurements, these two scores do not necessarily agree in all respects. Carcass score for example includes an actual measure of leanness. This is obtained after cutting the side. This cannot be done on sides to be processed for bacon. In general it may be said that the carcass grade is the more important from the practical feeders point of view, while the carcass score gives to the researcher the reason for the grades in that separate features of the carcass characteristics are more specifically measured.

From Table 3 it is evident that the chief effect of ration composition was in the extent of the development of the lean in the bacon rasher. In the barley-wheat mixture the area of the "pork chop muscle" of the rasher decreases steadily as more and more wheat replaces barley. The difference is probably of little practical importance when wheat constitutes up to 50% of the basal mixture. The wheat-oats combination also showed a small lean development as compared to the barley fed lots.

TABLE 3.—CARCASS MEASUREMENTS. EFFECT OF RATION

| Item | I Wheat 50 + Oats 50 | II Wheat 100 | III Wheat 75 + Barley 25 | IV Wheat 50 + Barley 50 | V Wheat 25 + Barley 75 | VI Barley 100 | VII Barley to 100 lbs. | VIII Barley to 150 lbs. | IX Wheat to 100 lbs. | X Wheat to 150 lbs. | Necessary difference between lot means |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Carcass wt. (lbs.) | 152 | 153 | 149 | 151 | 152 | 148 | 153 | 153 | 150 | 151 | 4.0 |
| Carcass length (ins.) | 30.4 | 30.1 | 30.3 | 31.0 | 30.4 | 30.1 | 30.3 | 30.4 | 29.8 | 30.2 | 0.5 |
| Shoulder fat (ins.) | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.6 | 1.6 | 1.7 | 1.6 | 0.2 |
| Area, eye of lean (sq. ins.) | 4.9 | 4.8 | 4.8 | 5.2 | 5.4 | 5.6 | 5.3 | 5.8 | 5.1 | 5.2 | 0.6 |
| Per cent lean in rasher | 39.3 | 38.9 | 40.6 | 42.4 | 43.8 | 43.8 | 40.1 | 43.6 | 42.9 | 42.6 | 3.3 |

The leanest carcasses of all, everything considered, were in: (1) the groups fed barley to 150 lb. and finished on wheat; (2) the 25% wheat—75% barley; and (3) those on straight barley. These pigs were among the more slowly gaining animals, and it is noteworthy that there was a statistically significant negative correlation between the area of the "eye of lean" and the daily gain to market weight. (See later).

Sex differences are marked in carcass characteristics, as shown in Table 4.

TABLE 4.—CARCASS MEASUREMENTS. EFFECT ON SEX.

| Item | Males | Females | Necessary Difference |
|---|---|---|---|
| Carcass score (%) | 70 | 81 | 4 |
| Carcass wt. (lbs.) | 151 | 152 | 2 |
| Carcass length (ins.) | 30.1 | 30.5 | 0.2 |
| Depth shoulder fat (ins.) | 1.8 | 1.6 | 0.1 |
| Depth back fat (ins.) | 1.2 | 1.0 | 0.06 |
| Belly thickness (ins.) | 0.8 | 0.7 | 0.06 |
| Area eye of lean (sq. in.) | 4.9 | 5.6 | 0.3 |
| Per cent lean in rasher | 39.1 | 44.5 | 1.5 |

There can be no doubt that at equal market weight (or carcass weights) the male pigs are fatter. This is the chief reason for the lower carcass score for males.

Carcass excellence for practical purposes is best indicated by the rail grading, since it is on this basis that bonus payments to the feeder are made. In connection with this index of excellence it must be remembered that it is subject to the personal factor, being the judgment of a grader. It is especially subject in these tests to variations resulting from the marketing of individual pigs at different times so that comparisons on the rail with other pigs of the test is not possible. Table 5 summarizes the grading records.

TABLE 5.—CARCASS GRADES

| Grade | I<br>Wheat 50 + Oats 50 | II<br>Wheat 100 | III<br>Wheat 75 + Barley 25 | IV<br>Wheat 50 + Barley 50 | V<br>Wheat 25 + Barley 75 | VI<br>Barley 100 | VII<br>Barley to 100 lbs. | VIII<br>Barley to 150 lbs. | IX<br>Wheat to 100 lbs. | X<br>Wheat to 150 lbs. |
|---|---|---|---|---|---|---|---|---|---|---|
| Males | | | | | | | | | | |
| A | 3 | 1 | 0 | 2 | 1 | 5 | 3 | 0 | 1 | 3 |
| B | 3 | 5 | 6 | 3 | 5 | 1 | 3 | 5 | 4 | 3 |
| C | | | | 1 | | | | 1 | 1 | |
| Females | | | | | | | | | | |
| A | 5 | 2 | 6 | 6 | 6 | 4 | 3 | 4 | 5 | 4 |
| B | 1 | 4 | 0 | 0 | 0 | 2 | 2 | 2 | 1 | 2 |
| C | | | | | | | | | | |
| All pigs | | | | | | | | | | |
| A | 8 | 3 | 6 | 8 | 7 | 9 | 6 | 4 | 6 | 7 |
| B | 4 | 9 | 6 | 3 | 5 | 3 | 5 | 7 | 5 | 5 |
| C | | | | 1 | | | | 1 | 1 | |

Perhaps the most striking feature of these data is the sex difference. It seems evident that at market weights of 200 lb. it is exceedingly difficult to produce on heavy wheat feeding male pigs which will bring bonuses for carcass excellence. The case of the females is sharply different, excepting possibly where barley is fed as the entire basal feed.

These sex differences alone are more clearly shown if presented irrespective of ration as follows:

| Sex | Grade of Carcass | | | Total carcasses |
|---|---|---|---|---|
| | *A* | *B* | *C* | |
| Males | 19 | 38 | 3 | 60 |
| Females | 45 | 14 | 0 | 59 |

It is difficult to know what this situation ultimately will mean. Must separate carcass standards for barrows and gilts be established?

It has already been shown at this station that some correction can be made by an adjustment in the marketing weights. Male pigs marketed 15 to 20 lb. lighter than the present accepted weight of 200 lb. results in an increase in the proportion of A grades. There is frequently a penalty in carcass score, however, for light weight carcasses. Type of pig, particularly with respect to length, is an important factor governing optimum marketing weights. Within a given type, there appears to be a difference in carcass characteristics of male and female pigs such that the latter are more suitable for high quality bacon as is it now graded.

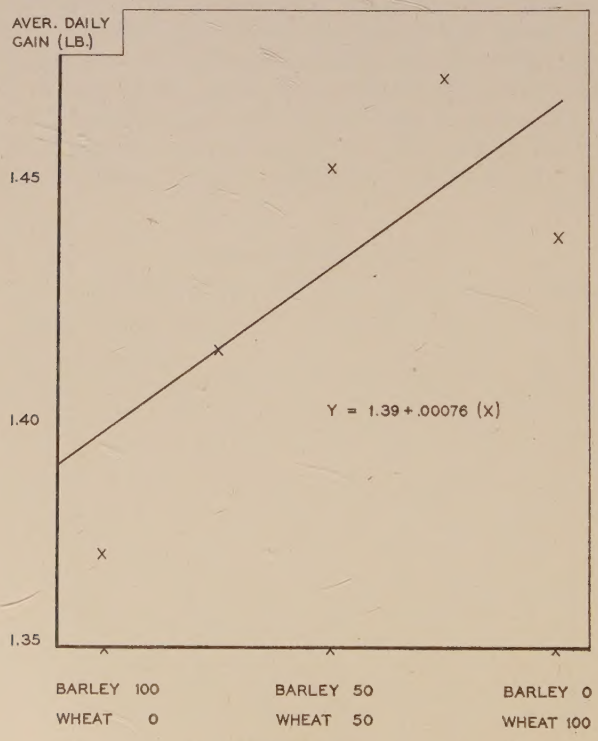


FIGURE 1

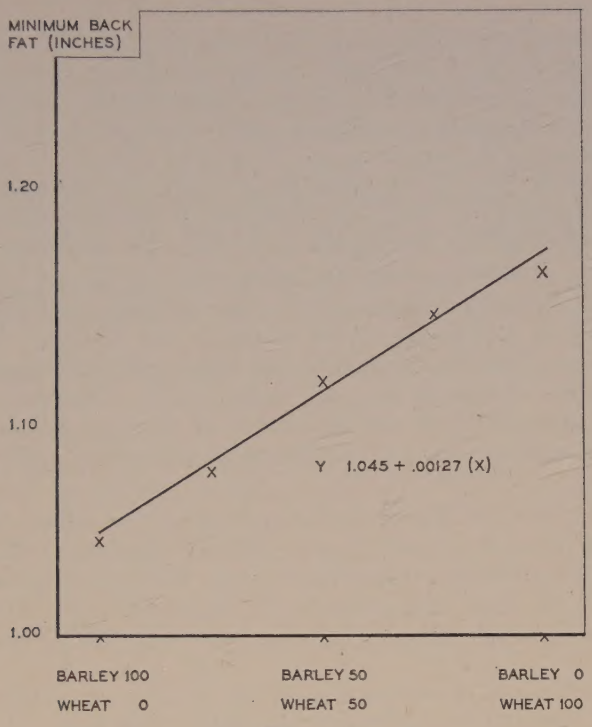


FIGURE 2

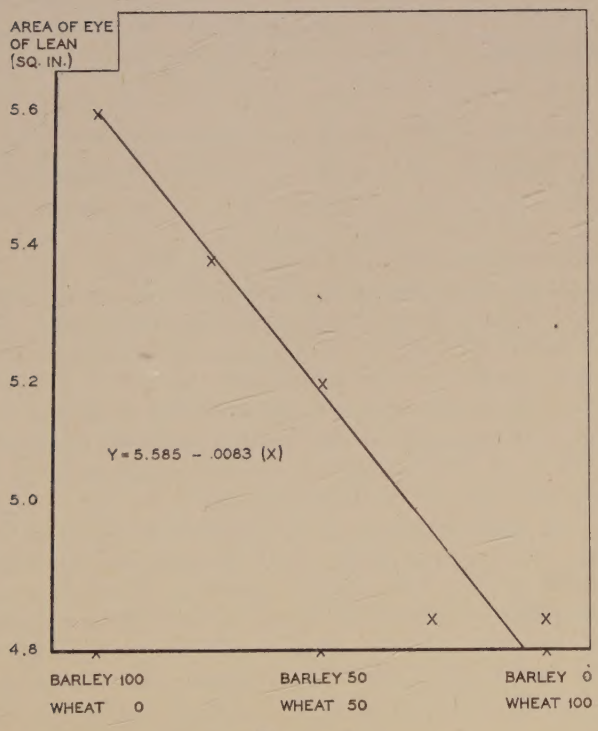


FIGURE 3

Some of the effects of replacing barley by wheat in the basal portion of the bacon hog ration are indicated by the data of Lots II to VI inclusive. Using the average values of each lot as single observations, simple regression coefficients were calculated showing for each replacement of 1% of barley with wheat the quantitative change in (1) rate of gain (lb.); (2) minimum back fat (in.); and (3) area of "pork chop muscle" in the rasher (sq. in). The regressions appear at first to be small, but it will be remembered that the effect of replacing half the barley with wheat for example, is 50 times the regression. The data are shown graphically in Figures 1 to 3.

There is no doubt that replacement of barley with wheat tends toward faster rates of gain and greater depth of fat on the carcass. The greater fatness is reflected also in a decrease in the amount of lean as measured by the area of the eye of lean of the pork chop muscle. Multiple correlation indicates that about 82% of the variability in the area of eye of lean is associated with rate of gain and with increased depth of the external fat layer.

The relation of rate of gain to the leanness of the bacon carcass is of some interest inasmuch as rate of gain may be affected by factors other than the introduction of wheat into the ration. Simple correlation between gains and "eye of lean" are statistically significant ($P$ .05) not only because of type of ration but also between pigs on identical rations.

TABLE 6.—SIMPLE CORRELATIONS AND REGRESSIONS, BETWEEN AREA OF EYE OF LEAN (SQ. IN.) AND THE INDEPENDENT VARIABLE SHOWN.

| Independent variable | Between lots | | Between pigs within lots | |
|---|---|---|---|---|
| | $r$ | $b$ | $r$ | $b$ |
| Daily gain to 110 lbs. | −.85 | −4.42 | −.23 | −1.15 |
| Daily gain 110 lbs. to 200 lbs. | −.66 | −4.65 | −.30 | −0.99 |
| Daily gain weaning to market | −.87 | −5.79 | −.32 | −1.54 |

This raises several practical problems in pig raising. Is it possible that older pigs can always be expected to have leaner carcasses than pigs that have made more rapid gains to the 200-lb. market weight? If so, why? In these trials neither rate of gain nor shipping age is significantly correlated with carcass score either between different rations or between pigs on identical rations. However, area of eye of lean was significantly correlated with shipping age between pigs on identical rations, *but not between rations.*

Can this effect be attained by the simple expedient of curtailing feed during the fattening period? Correspondence from McMeekin[4] indicates this to be the case, and would appear to support the hypothesis that until the pig is about four months of age the growth made normally tends to consist principally of bone and muscle regardless of kind of ration. Full feeding during this time permits full and rapid development of these tissues. The succeeding growth, however, is normally one predominantly of fattening if liberal feed is available. Some frame and muscle growth still

[4] Dr. C. P. McMeekin, Ruakura Animal Research Station, Hamilton, New Zealand. Correspondence to author, December 1943.

continued nevertheless, and under limited feeding this becomes a relatively larger part of the live weight gains. The end result in the 200-lb. pig should be a carcass of relatively greater leanness than that obtained from the pig that has been full fed during the fattening period.

The feeding trials herein reported yield no data from which the validity of this hypothesis can be judged, though the desirability of such information is obvious. (Tests of this hypothesis are now in progress at this station).

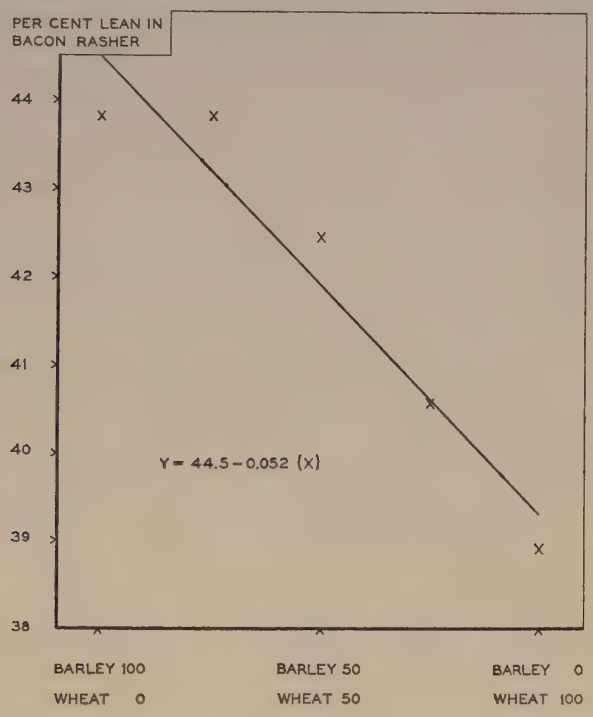


FIGURE 4

As to whether wheat is best used in the early part of the feeding period or in the final fattening period is not clearly indicated in these tests. No consistent significant trends or differences are apparent between these four lots in any respect. In actual gains for example the group fed wheat to 100 lb. and finished on barley stood first, followed by those fed barley to 100 lb. and finished on wheat. On the other hand feeding pigs on wheat to 150 lb. and finishing on barley stood above barley to 150 lb. with wheat finishing. About all that can be said from the figures available is that the pigs starting on barley until 150 lb. made the slowest gains of any of the 10 lots, but had carcasses showing a percentage lean comparable to those on pure barley or barley 75-wheat 25 mixture. These three lots ranked first in percentage lean (43.8; 43.8; and 43.6); followed by the two starting on wheat and finishing on barley, and the barley 50-wheat 50 mixture (42.9; 42.6; and 42.4). Barley to 100 lb. followed by wheat to finish and the barley 25-wheat 75 mixture was next (40.6; 40.1); and last were oats 50-wheat 50, and pure wheat (39.3; 38.9).

If these lots show anything at all it is merely confirmation of the evidence from the lots fed mixtures of barley and wheat that wheat in general tends to cause greater fattening rate and a decrease in the amount and porportion of lean tissue in the bacon hog carcass.

The wheat-oats mixture proved exceptionally palatable and rate of gain was the greatest of all lots in the trial. The carcass data, however, indicate that oats does not counteract the "wheat effect" on degree of fattening or lean development. Rail grade, which cannot include a direct observation of lean development, showed 66% bonus carcass for wheat-oats as compared to 66% for barley 50-wheat 50, and 75% for straight barley.

The reasons for the fattening effect of wheat may be several. The fibre content as compared to barley is smaller and fibre is largely indigestible by swine. Thus with equal quantities eaten, the wheat rations would contain more digestible nutrients than barley. This should mean faster gains.

On the other hand oats contain more fibre than barley. Nevertheless the pigs consuming the wheat 50-oat 50 mixtures gained more rapidly than did those on the wheat 50-barley 50 ration. It is true the wheat-oat group ate more feed—just enough more that the efficiency of the two rations was the same.

In view of the previous findings in this series of studies on wheat and barley concerning the effects of wheat germ on rate of fattening, and the known relation between thiamin and fat from carbohydrate, one wonders whether the fact that oats carries the highest thiamin content of all cereal grains with wheat next is not of significance.

## CONCLUSIONS

The data from these feeding trials confirm previous findings in this series of studies on the value of coarse grain for bacon hog production to the effect that as compared to barley wheat tends to cause more rapid live weight gains, and on pigs marketed at 200 pounds results in fatter carcasses. The latter effect is sufficiently pronounced in rations containing over 50% wheat (in the basal portion) to be of practical significance in reducing the market returns.

Male pigs appear to be more subject to carcass damage from heavy wheat feeding than females, presumably because of more rapid maturing of the male sex.

There is evidence that leanness of the bacon rasher is correlated with rate of live weight gain to 200 lb. which suggests that restricting feed (i.e., total digestible nutrients) intake during the fattening period might result in leaner carcasses regardless of kind of ration.

## ACKNOWLEDGMENT

It is a pleasuve to acknowledge the continued interest in, and generous financial support of this series of studies on the feeding value of Western Canadian Grains by the Canadian Co-operative Wheat Producers Limited.

# BLACK ROT OF RUTABAGAS

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[Received for publication December 5, 1944]

Black rot of table rutabagas has been increasing in severity since 1940 in many sections of Ontario, necessitating a study of the problem to formulate recommendations in an endeavour to bring the disease under control.

Since little information was available concerning black rot on this particular host, much preliminary investigation was necessary to ascertain fundamental information before specific phases of the problem could be studied. The present paper will give some idea of the information already obtained, with recommendations suggested to assist in bringing the disease under control.

## HISTORY AND DISTRIBUTION

Black rot of cruciferous plants was one of the earliest discovered bacterial diseases of plants, being first described on cabbages by Garman in 1891 (4). Two years later Pammel (5) published one of the first reports of the disease on rutabagas and turnips. Since that time there have been many records in the literature of various etiologic, ecologic and economic phases of the disease on other cruciferous hosts.

The disease was reported on rutabagas in Ontario in 1907 (2) and appears to be present wherever crucifers are grown. Although present in Ontario for years, it did not become of significant economic importance until 1939–1940. The severity and amount of the disease varies in different districts throughout the province, but being present in all, is annually a potential menace to the crop. Although black rot is present in Quebec and the Maritime Provinces, it is apparently of little economic importance there. The disease situation in the Western Provinces is not known.

## SYMPTOMS OF THE DISEASE

The earliest visible symptom on the leaves is the appearance of small water-soaked areas most frequently along the margin at the terminus of a vein, but under optimum conditions for infection, on any part of the leaf. As the water-soaked areas enlarge, they turn yellow and the earliest infected portions die making yellow bordered lesions of necrotic tissue, in which the small veins are characteristically dark brown to black in colour (Figure 2B). When originating on the edges of the leaves the lesions are roughly triangular in shape with the apex toward the leaf base, infections increase in size, several may coalesce, and progress towards the midrib then down the leaf which eventually dies and falls from the plant.

Although black rot infected leaves become chlorotic, all chlorotic leaves are not necessarily infected with the disease since chlorosis and defoliation may result from unfavourable environmental conditions. If

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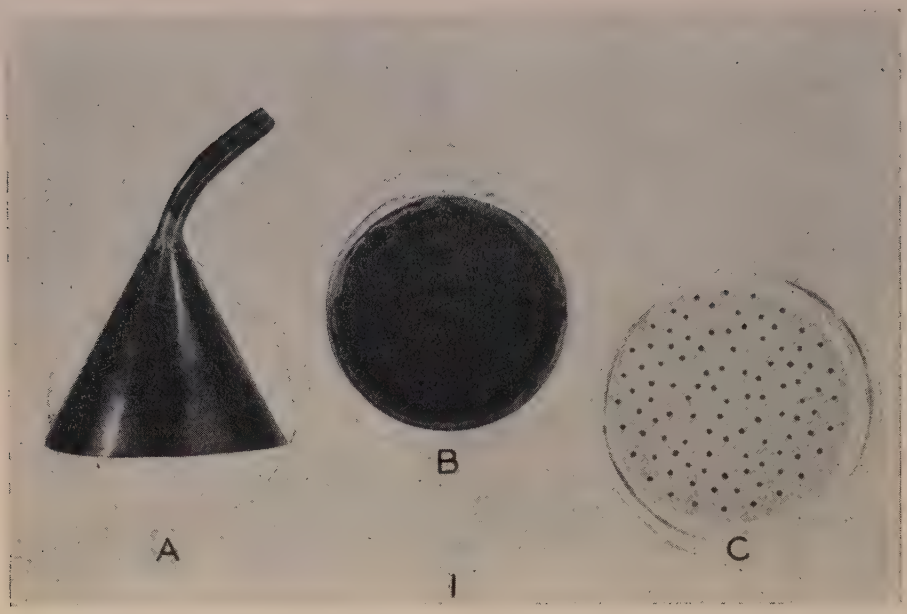


FIGURE 1. A, suction seed counter; B, base of cone showing 100 holes; and C, seeds in culture dish as placed by counter.

black rot is the causal factor, partially dead leaves will have chlorotic areas separating healthy and necrotic tissues and the characteristic dark veining.

In black rot infected fields where leaf spots caused by *Alternaria* or *Cercosporella* spp. are present, black rot has often been observed associated with the fungus lesions. In these cases, the necrotic area is usually regular in outline, lighter in colour and more papery in appearance, but having the characteristic yellow margins of typical black rot lesions.

Symptoms in the roots are a blackening of the vascular tissue first in localized areas of the vascular ring just beneath the cortical layer (Figure 7) and in severe cases scattered throughout the body of the root (Figure 9). Since the infection usually enters the root from the top through the vascular connections with infected leaves, the amount of discoloration is largely dependent on the severity of leaf infection. The blackening occurs first in the crown, later following the vascular strands to the base of the root (Figure 8). If infection enters from the soil, as sometimes occurs, the blackening progresses upwards instead of downwards. The disease progresses

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FIGURE 2. A, Healthy leaf and B, leaf showing typical symptoms of black rot. Note dark veins in chlorotic areas.

FIGURE 3 AND 4. Seedlings three weeks old showing black rot infection on all cotyledons (chlorotic and necrotic areas). Slightly further advanced in 3 than in 4.

FIGURE 5. Healthy seedling, same age as in Figure 3 and 4.

FIGURE 6. Seedlings grown from artificially inoculated seed, A, disinfected with Semesan before planting and B, not disinfected.

See Opposite Page

during the post-harvest period at a rate varying with the severity of infection and with the storage environment, until the root becomes partially or wholly pervaded by a spongy dry rot (Figure 10).

When seed is infected, and young plants are not killed before emergence, either one or both of the cotyledons will show the disease at about the time the second leaves have developed. The symptoms appear as a marginal chlorosis, and then necrosis, usually in the apical indentation at the end of the main veins (Figures 3 and 4). Infected cotyledons die prematurely, stunt the seedling's growth (compare Figures 4 and 5), and the disease spreads to the new leaves as they develop.

## THE PATHOGEN

Black rot of rutabagas is caused by the bacterial plant pathogen *Xanthomonas campestris* (Pamm.) Dowson, the etiological and ecological relations of which have been thoroughly dealt with on many cruciferous hosts (3 and 6). The causal organism can be readily isolated from diseased leaf or root tissue and will remain viable and retain its pathogenicity for considerable time. The organism was still pathogenic after storage for a year at 35° to 40° F., but remained viable for only four to five months at room temperature.

Throughout the progress of these investigations, the presence of the disease has been established by isolation and culture of the organism, and confirmed by symptom expression on and re-isolation from artificially inoculated leaves of young swede turnip plants.

## EXPERIMENTAL

### *Seed Transmission of the Disease*

It has been proved that black rot can be seed transmitted and that the pathogen can live on cabbage and Brussel sprouts seed for at least 3 years (1). During the years 1939–1942 when black rot was increasing in Ontario, the acreage planted to the recently introduced Laurentian variety was increasing to such an extent that all available seed was being planted the spring after it was grown. It was thought that much of the disease may have been introduced on this fresh seed. Accordingly, commercial seed was obtained from as many sources as possible and tested for the presence of the pathogen; 500 to 800 seeds from each sample were counted and plated on potato dextrose agar jelly with the suction counter illustrated in Figure 1. All bacteria which developed from the seeds were isolated and cultured and those which resembled the pathogen were used for artificial inoculations to determine their pathogenicity. Up to and including November 30, 1943, sixty-five samples were tested. From the 35,700 seeds plated, 5,236 isolations were made, a number of which were pathogenic. In the samples tested the seeds infected varied from 0 to 6%.

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FIGURE 7. Primary symptoms of black rot.

FIGURE 8. Black rot inside the cortical tissues of the root resulting from an infection similar to that shown in Figure 7.

FIGURE 9. Severely infected root as it appears at harvest time.

FIGURE 10. Severely infected root after five months in storage. Note the dry spongy nature of the decay.

See Opposite Page

In a test conducted with 12 seed plants grown from black rot infected roots, although the disease was sufficiently severe to rot many of the stalks prior to blossoming and seed formation, *X. campestris* could not be isolated from any stalk at a distance greater than 7 inches from the infected root and in a number of cases the pathogen did not ascend the stalk more than 1 inch; 500 seeds from each plant were plated, but in no case was the pathogen recovered.

*Viability of Pathogen on the Seed*

Since *X. campestris* is present on the seed, it seemed desirable to obtain some information on the length of time the pathogen would remain viable following natural and artificial contamination. In the seed tested, 56% of the samples harvested in 1942, 33 from 1941, and a single sample from 1940, contained seeds from which *X. campestris* was isolated.

One sample of 1942 grown seed showed 3.4% infected seed on May 18, 1943, but when retested on November 3 after having been stored in the laboratory during the intervening 24 weeks, showed only 0.2% infection. The fact that infection decreases with the ageing of the turnip seed may explain, in a measure, the correlation between the shortage of seed stocks and the increase of black rot in Ontario in recent years.

On a number of occasions, samples of clean seed were inoculated with water suspensions of *X. campestris*, dried at room temperature, and stored in various environments. Periodic isolations from this seed recovered the pathogen in one case 4 months after inoculation, but viability decreased very rapidly after 2 months. Whatever the explanation, it is quite evident that the pathogen remains viable for much longer periods on naturally contaminated seed.

*Seed Disinfection*

Although it is realized that treatment with hot water is probably the most effective method of killing black rot bacteria associated with the seed, the difficulties involved in its use make it unsatisfactory as a general recommendation.

Tests were conducted with two objects in view; first, to find a disinfectant that was relatively simple to apply and capable of killing the pathogenic bacteria; and second, one that in addition to being effective, could be applied to the seed at its source before packaging, to relieve growers of the necessity of treating their own seed. In the latter case, the possible detrimental effect on the seed when treated several months in advance of planting, had to be determined.

All tests on the efficacy of the various disinfectants were made with seed artificially inoculated by soaking for 10 minutes in a water suspension of *X. campestris*, dried at room temperature, disinfected the following day and planted in flats of steamed soil. The number of diseased seedlings appearing in the flats was taken as an index of the efficiency of the chemical tested.

The effect of the disinfectant on the viability of the seed was recorded by germination tests on filter paper.

In the following table, the control obtained by the disinfectants mentioned is recorded as the average of five separate tests with 200 seeds each.

TABLE 1.—PERCENTAGE GERMINATION AND AMOUNT OF DISEASE IN ARTIFICIALLY INOCULATED SEED TREATED WITH VARIOUS DISINFECTANTS, AND EFFECT OF DISINFECTANTS ON GERMINATION

| Disinfectant | Germination | Black Rot | Germination of non-inoculated seed stored in paper bags after disinfection | | |
|---|---|---|---|---|---|
| | | | 2 days | 8 months | 17 months |
| | % | % | % | % | % |
| $HgCl_2$ 1/1000 | 92 | 0.32 | — | — | — |
| Semesan | 89.30 | 1.34 | 98.5 | 99.0 | 95.0 |
| Ceresan | 57.50 | 1.22 | 86.5 | 67.5* | 52.0† |
| Zinc oxide | 94.60 | 1.90 | 97.0 | 96.0 | 94.0 |
| Spergon | 93.50 | 2.14 | 97.0 | 97.5 | 100.0 |
| Cuprocide | 91.80 | 1.63 | 99.5 | 99.5 | 99.0 |
| Thiosan | 93.90 | 12.14 | 97.0 | 96.5 | 94.5 |
| Arasan | 93.55 | 16.71 | 91.0 | 95.0 | 91.5 |
| Fermate | 92.60 | 21.06 | 97.5 | 98.5 | 97.5 |
| None | 91.40 | 46.17 | 98.5 | 99.5 | 98.5 |
| Not inoculated | 93.70 | 0.00 | 98.0 | 99.0 | 97.5 |

* 10 weeks.
† 11.5 months.

*Soil Transmission of the Disease*

It has been proved that the disease can be initiated by the planting of infected seed and it is also known that the spread from leaf to leaf and thence to the root takes place quite rapidly under warm humid conditions. The possibility of infection from the soil however, though suggested in some cases, had not been definitely established. To prove this point, steam sterilized soil was inoculated with a quantity of finely ground infected swede turnip roots, then planted with seedlings of Essex Rape, and Purple King and Laurentian swede turnip on November 24, 1942.

During the five months the plants remained in the soil, there was some variation in their rate of growth and a number of the plants developed typical black rot lesions on some of their leaves. When harvested, all roots were pulled and sliced horizontally every quarter inch to determine if the disease was present and whether the infection had progressed upwards or downwards in the root. This could be quite readily determined by comparing the intensity of the vascular discoloration in successive slices.

TABLE 2.—PERCENTAGE OCCURRENCE OF TYPES OF INFECTION OF ROOTS OF CRUCIFEROUS PLANTS GROWING IN ARTIFICIALLY INOCULATED SOIL

| Crop | Healthy roots | Infection upwards through root | Infection downwards through crown | Infection in both directions |
|---|---|---|---|---|
| Rape | 75.0 | 10.7 | 3.6 | 10.7 |
| Purple King | 25.0 | 25.0 | 0.0 | 50.0 |
| Laurentian | 7.1 | 64.3 | 10.7 | 17.9 |

It was also demonstrated that similar infection will occur after a water suspension of a pure culture of the pathogen has been added to the soil in which young seedlings were planted.

This clearly demonstrates that the presence of the pathogen in the soil can be a potential source of infection to the crop.

*Field Experiments and observations during the 1943 Growing Season*

There was extremely heavy and frequent precipitation during the early part of the season with the result that most fields were sown considerably later than usual and many had to be resown because of heavy rains, immediately following sowing. However, subsequent environmental conditions were ideal for rapid growth during the early summer, but later in the season growth was arrested by drought, resulting in lack of size in many of the late sowings.

At regular intervals during the growing season, surveys of several of the largest producing areas were made in order to check on the general black rot situation, to compare fields planted with disinfected and untreated seed and to obtain information on disease spread and other factors relating to the problem.

Six lots of seed were treated at the laboratory and planted by farmers in various districts. All other disinfections were done by the individual growers themselves according to recommendations contained in a circular distributed from this laboratory, but no check was made on the accuracy of the methods employed.

Although there were a number of fields planted with untreated seed which showed very little black rot and some fields planted with disinfected seed which showed a comparatively high disease content, by and large, fields planted with disinfected seed had a more even stand, were more vigorous, and had appreciably less disease than those where untreated seed was used.

Twenty fields planted with seed disinfected with either Semesan or mercuric chloride, and 12 planted with untreated seed were critically examined with results as shown in the following table.

TABLE 3.—A COMPARISON OF THE AMOUNT OF BLACK ROT IN FIELDS PLANTED WITH DISINFECTED AND UNTREATED SEED

| Amount of Disease | Disinfected Seed | Untreated Seed |
|---|---|---|
| None | 2 | 0 |
| Trace | 15 | 2 |
| Slight | 2 | 3 |
| Moderate | 1 | 1 |
| Severe | 0 | 6 |

There were no marketable rutabagas from three of the six severely diseased fields planted with untreated seed, while in the remaining three only part was saleable.

The fact, already shown, that different samples of seed vary greatly in their disease content, may readily explain the variation in the amount

of disease in fields planted with untreated seed. Although there is no way of determining the origin of infections responsible for the disease in fields planted with disinfected seed, any one or a combination of three factors may have a bearing on the condition. First, seed disinfection is seldom perfect, and since some 190,000 seeds are sown on every acre, it is quite possible that the disease might originate from the few imperfectly disinfected seeds that produce diseased plants. There is also the possibility of infection from the soil or from other cruciferous plants in close proximity to the fields.

It was apparent that under favourable environmental conditions the disease can spread very rapidly through fields by splashing of rain, insect transmission, and working in the crop when the foliage is not dry. Many diseased fields revealed the presence of definite infection centres, generally located along surface washes or in depressions where the ground remained moist for considerable periods and from which the disease radiated.

Humid conditions are essential for the spread of the disease because although there was a rapid increase in its incidence during early summer, little or no spread took place, even in severely infected fields, in late summer and early fall when drier conditions prevailed.

*Field observations during the 1944 Season*

The beneficial results obtained from the use of disinfected seed in 1943 were so striking that growers and distributors were convinced that nothing but treated seed should be planted.

As a result it is estimated that over 95% of the seed planted in 1944 was disinfected either before packaging, by distributors, or before being sown, by the growers themselves. In most of the commercial disinfection, Semesan was used but some Arasan treated seed also reached the market.

Although weather conditions were favourable for the development of black rot, especially in the late summer and fall, the disease was of little economic importance where Semesan or mercuric chloride disinfected seed was used. However, in a number of instances where untreated seed was planted the disease was severe.

## CONTROL OF THE DISEASE

Although there are still many phases of the black rot problem on which there is no information available, and repetition of many of the tests herein described would greatly increase their value, nevertheless from the information accumulated to date, it is possible to formulate certain control recommendations that should aid materially in the reduction of the disease in this province.

Never plant untreated seed. If it has not been disinfected before reaching the retail market, it should be treated by the grower before planting with either Semesan powder or a liquid solution of mercuric chloride (corrosive sublimate). If Semesan is used, half fill a screw capped container with seed and add the recommended quantity of disinfectant. Shake the contents vigorously until every seed is thoroughly coated with the powder, then screen off the excess before sowing the seed. It is beneficial to treat well in advance of planting, wrapping disinfected seed in a clean paper

bag, not the original container, until ready to use. When treating with corrosive sublimate, make a water solution 1–1000 (1 tablet in a pint of water) in a non-metallic container. Place the seed loosely in a porous cotton or cheesecloth bag and soak in the solution for 20 minutes, keeping the seed immersed at all times by prodding with a blunt stick. Remove seed from the bag and dry as rapidly as possible. Best results will be obtained if seed is sown as soon as it will flow freely. Utmost care should be used in handling all disinfectants for they are deadly poisonous.

Practise at least a 4-year rotation and do not plant rutabagas in the same field or immediately adjacent to one which grew a cruciferous crop the previous year.

If possible, it is advisable to plant in a well drained field where there is little surface washing and few depressions where water is liable to collect and the soil remain soaked for any length of time, particularly if the surface drainage comes from farm buildings or a field previously infected with black rot.

When cleaning out the root cellar, never put refuse on the manure or compost pile where it could be again returned to the land; and after the removal of debris, all walls, floor and ceiling should be disinfected by thoroughly spraying with a solution of bluestone (copper sulphate) 1 lb. in 10 gallons water, or formalin, 1 pint in 6 gallons water.

If a field of rutabagas becomes severely infected with black rot just before harvest time, it is advisable to dispose of the crop for immediate consumption, since in a comparatively short time the disease can infect the roots sufficiently to impair their market value seriously. Roots from a diseased field should never be placed in storage for future shipment because the disease is sure to cause severe loss by spreading through the stored stock.

## SUMMARY

Black rot of rutabagas has been increasing in Ontario since 1939, resulting in severe losses to many producers. The rapid increase in popularity of the Laurentian variety, necessitating the use of fresh seed, may have considerable bearing on the situation.

The symptoms of black rot, which affects cruciferous hosts generally, are characteristic and not easily confused with other leaf and root diseases, the pathogen *Xanthamonas campestris* is a seed borne vascular parasite, quite readily isolated and cultured.

Chemical seed disinfectants vary in their lethal effects upon the pathogen. Mercuric chloride and Semesan have given the most satisfactory results.

Infection may enter the plant through the leaves, or from the soil through the roots and under humid conditions spreads very rapidly.

In 1943 striking reductions in the amount of black rot were noted in fields planted with disinfected seed, and in 1944 when over 95% of the seed was disinfected the disease was not of economic importance.

Recommendations for controlling the disease are outlined.

## ACKNOWLEDGMENT

Sincere thanks are accorded Dr. G. H. Berkeley for his keen interest and helpful suggestions throughout the progress of this investigation.

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# SHATTERING IN OATS[1]

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The more extensive use of the combine has created a greater interest in varieties that will withstand weather conditions that favour shattering. In the case of oats, the comparatively loose attachment of the spikelets favours shattering when an over mature crop is subjected to high winds, rain, hail or even ordinary handling. In studying the question of varietal resistance to shattering in oats at Ottawa over a period of two years, data have been collected which may be of interest to those working with this crop.

Very little investigational work has apparently been done on shattering in oats and only one reference has come to the notice of the writer, i.e., "Experimentelle Untersuchungen uber des Ausfallen der Korner bei Hafer und Weizen", by F. Priebs, in Bot. Archiv. 27 ; 1-59, 1929. This paper deals with the problem of shattering in oats, first in relation to the effect of weather and second on the influence of spikelet attachment. The data were obtained by using two methods of artificial shattering, i.e., the "drop" and the "shake" methods. In the former the panicles were dropped from a distance of 90 cm. 8 times, and in the latter the panicles were subjected to horizontal shaking covering a distance of 46 mm. for 90 seconds or 375 times. Apparently weather conditions during the growing season are associated with shattering in oats, and the work reported by Priebs shows that high precipitation during the period of greatest growth causes more shattering.

A further effect of high precipitation during this period is that it hinders the development of sclerenchyma tissue at the point of spikelet attachment therefore increasing the tendency to shatter. In dealing with the spikelet attachment this author states that the size of peduncle base, and the angle of spikelet attachment are directly associated with shattering. The larger the peduncle base and the closer the approach to a right angle spikelet base, the greater the resistance to shattering.

## MATERIALS AND METHODS

The object of the work on this problem at Ottawa has been to determine whether varieties differ in shattering tendencies and to make use of such findings in the oat breeding program. On account of the difficulties of studying shattering under natural conditions, an effort was made to use machine shaking as an index to varietal resistance, although both methods have been used in accumulating the data presented below.

In 1941 eight varieties were studied for shattering resistance and panicles were collected from each variety in a quadruplicate test, the samples being taken from the outside rows in 5 rod-row plots. A duplicate set of 10 sample panicles was taken at the time of maturity and a single

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set 10 days later. With 1 of the duplicate sets of 10, spikelet counts were made to determine the actual loss in field shattering up to full maturity. Similar counts were made on the panicles collected 10 days after maturity. The duplicate set of 10 panicles collected at maturity was subjected to machine shaking, the extent of agitation being 215 shakes a minute over a distance of $7\frac{1}{2}$ inches. In the same year, the same set of 8 varieties was grown in a special replicated shattering test at the Experimental Farm, Indian Head, Sask. The data obtained from this test were based on the number of shattered spikelets per panicle per row. One count was made at maturity and a second, 5 days later following an extremely high wind.

In 1942 this work was repeated at Ottawa with 12 varieties. Panicles were collected three times at intervals of 10 days, the first being taken at maturity. Duplicate samples were taken on each of the three dates for machine shaking. Shattering data were obtained as noted in the 1941 tests at Ottawa.

TABLE 1.—PERCENTAGE OF FIELD AND MACHINE SHATTERING IN EIGHT OAT VARIETIES AT OTTAWA IN 1941

| Variety | 1st cutting | | 2nd cutting* |
|---|---|---|---|
| | Field | Machine | Field |
| Dasix | 0.9 | 9.6 | 2.8 |
| Vanguard | 5.4 | 14.0 | 7.0 |
| Onward | 2.7 | 7.5 | 19.9 |
| Bambu | 1.3 | 22.7 | 23.9 |
| Lasalle | 4.4 | 17.9 | 21.5 |
| Len. 51–2 | 3.4 | 28.3 | 28.8 |
| Banville | 6.7 | 32.7 | 29.5 |
| Ardri | 4.9 | 19.9 | 61.3 |
| Sig. difference | 4.3 | 12.0 | 23.7 |

* No samples taken for machine shaking in 2nd cutting.

The varieties included in this test were chosen as a result of preliminary field observation and were expected to show as wide a range of shatterability as possible within the limits of the material available and without using varieties from wild species. The varieties Onward, Bambu, and Ardri are introductions from foreign sources. Len. 51–2 is a sister selection of Vanguard, and Banville is a selection of the Tartar King type. The other three varieties are grown commercially in Canada.

The variance analysis, when applied to the 1941 data at Ottawa shows a significant difference in percentage shattering between varieties in each of the three treatments. The data also show that machine shaking can be used as a means of determining differences between varieties in shatterability.

TABLE 2.—PERCENTAGE OF FIELD SHATTERING IN EIGHT OAT VARIETIES AT INDIAN HEAD, SASK., 1941

| Variety | Percentage panicles showing shattering | |
|---|---|---|
| | Taken at maturity | Taken 5 days after maturity following heavy Wind |
| Dasix | 10.6 | 23.5 |
| Onward | 18.7 | 7.1 |
| Vanguard | 20.7 | 60.8 |
| Bambu | 21.3 | 36.4 |
| Lasalle | 21.5 | 33.3 |
| Len. 51–2 | 25.1 | 52.0 |
| Banville | 26.8 | 34.6 |
| Ardri | 33.9 | 44.4 |

The data from the Indian Head test in Table 2 were not taken on the basis of percentage of shattered spikelets, but rather on the number of panicles showing shattered spikelets. The Indian Head data are therefor not directly comparable with those from the Ottawa tests, but indicate in a general way that certain varieties are more resistant to shattering than others.

TABLE 3.—PERCENTAGE OF FIELD AND MACHINE SHATTERING IN TWELVE OAT VARIETIES AT OTTAWA IN 1942

| Variety | 1st cutting | | 2nd cutting | | 3rd cutting | | Average for 3 cuttings | |
|---|---|---|---|---|---|---|---|---|
| | Field | Machine | Field | Machine | Field | Machine | Field | Machine |
| Ajax | 0.1 | 0.7 | 0.9 | 3.7 | 3.8 | 16.5 | 1.6 | 6.9 |
| Dasix | 0.9 | 1.1 | 1.7 | 11.4 | 2.2 | 13.3 | 1.6 | 8.6 |
| Erban | 0.2 | 0.8 | 0.7 | 4.9 | 5.6 | 13.5 | 2.1 | 6.4 |
| Ripon | 0.7 | 1.7 | 0.9 | 13.1 | 4.9 | 19.6 | 2.1 | 11.4 |
| Vanguard | 0.8 | 3.3 | 1.3 | 14.7 | 6.9 | 29.4 | 3.0 | 15.8 |
| Victory | 1.4 | 2.6 | 1.1 | 14.3 | 7.3 | 22.6 | 3.2 | 13.2 |
| Beaver | 1.8 | 8.4 | 2.9 | 12.3 | 7.1 | 28.5 | 3.9 | 16.4 |
| Roxton | 0.1 | 1.8 | 0.4 | 9.9 | 12.4 | 10.5 | 4.3 | 7.4 |
| Gopher | 0.1 | 2.0 | 1.2 | 8.1 | 12.1 | 15.5 | 4.4 | 8.5 |
| Ardri | 0.8 | 2.6 | 1.6 | 16.3 | 17.5 | 28.0 | 6.6 | 15.6 |
| Banville | 0.5 | 6.3 | 6.4 | 30.8 | 13.6 | 40.9 | 6.8 | 26.0 |
| Mabel | 2.9 | 4.1 | 6.7 | 16.8 | 12.9 | 38.7 | 7.5 | 19.8 |
| Sig. difference | 1.4 | 2.4 | 2.7 | 6.0 | None | 7.2 | | |

The data on the 1942 Ottawa Test, as shown in Table 3, further indicate a difference between varieties in shatterability. In this test a wider range of varieties was used and with the exception of the data obtained from the field shattering in the 3rd cutting, the analysis of variance shows a significant difference between varieties. The 1942 data also show that machine shaking as a means of creating artificial shattering can be used satisfactorily in studying differences between varieties.

## DISCUSSION

The data presented in this paper appear to establish the fact that varieties of oats differ in shattering tendencies. Both in 1941 and 1942 the variety Dasix has shown high resistance to shattering, while from the 1942 data it would seem that Ajax could also be put into the resistant class. Among the varieties showing the tendency to shatter easily in both years are Banville and Ardri, while in 1942, Mabel also shows high susceptibility.

There is no indication from the data presented that shattering in oats is associated with early maturity or panicle type, except in the case of true cluster type varieties, e.g. Banville. While there is a tendency for some of the commonly grown varieties to produce more upright panicle branches than others and thus give the appearance of semi-cluster panicles, the above data do not show that this characteristic is related to shattering. Ajax, for example, might be classed as having more of a cluster type panicle than Dasix, and yet these two varieties are in the same class as regards shattering tendencies.

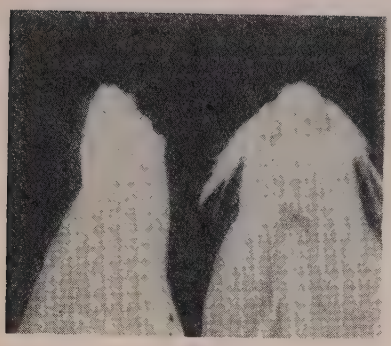
With regard to the relation of time of cutting to shattering tendency, it is obvious that the longer a mature crop stands in the field, the greater will it shatter both from handling and from adverse weather conditions. The 1942 data show that at the third cutting or 20 days after maturity, Ardri had shattered 17% under natural field conditions. In 1941, the same variety had shattered 61% at the second cutting or 10 days after maturity.

## ATTACHMENT OF SPIKELET

According to the work of Priebs, referred to earlier in this paper, the basal attachment of the spikelet is an important character in determining the resistance or susceptibility to shattering in oats. In endeavouring to apply the findings of this author to the varieties that have been used in the data under discussion, critical studies were made by the junior author on the size and angle of the spikelet base in the case of six varieties. The varieties Mabel and Banville were studied as representing extreme shattering susceptibility, Victory and Gopher were chosen as being somewhat intermediate and Ajax and Dasix as being partially resistant.

In the case of varieties susceptible to shattering, the spikelet base approaches a 45° angle as indicated in the variety Mabel (Figure 1). This sharp angle of attachment resembles that of wild oats. On the other hand with varieties that resist shattering, the angle of spikelet attachment is much less acute and in some cases approaches a right angle. The latter is illustrated in the variety Ajax (Figure 1).

Other factors that appear to be associated with shattering are the actual area of basal attachment of the spikelet and the thickness of the sclerenchyma tissue surrounding the spikelet base. In the material studied, the amount of variation in size of base and thickness of sclerenchyma tissue was found to be considerable, but nevertheless, the indications were that these two characteristics were definitely related to the ability of the spikelet to resist shattering under adverse weather conditions. More work needs to be done on this phase of the problem.



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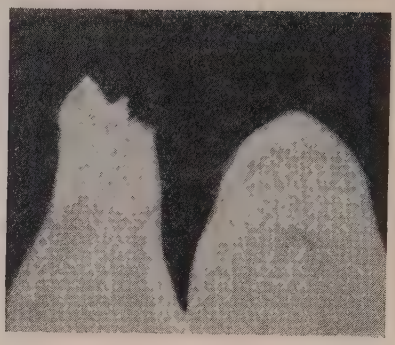

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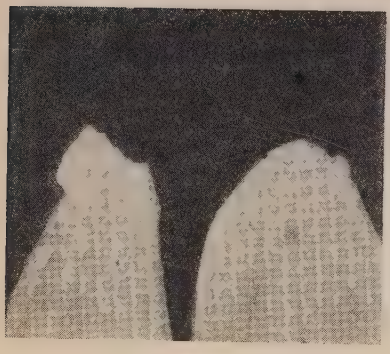

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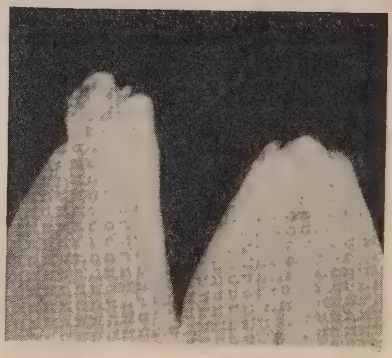
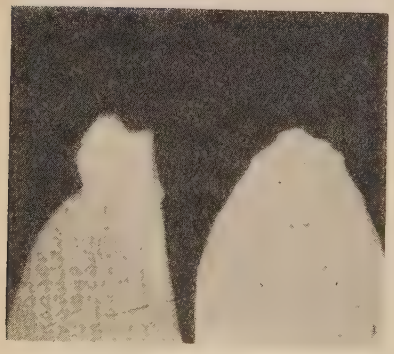
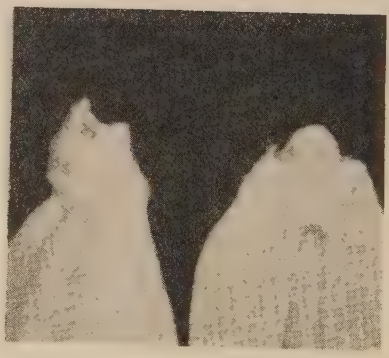


GOPHER



AJAX



DASIX

FIGURE 1. Size and angle of spikelet base.

## SUMMARY

1. Varietal differences in resistance to shattering in oats have been established in the case of Canadian varieties.

2. Machine shaking of panicles can be used to give an index of varietal resistance to shattering.

3. The greater the angle of spikelet attachment to the peduncle, the greater the tendency to shatter.

4. It is probable that the greater the total area of the spikelet base and the thicker the sclerenchyma tissue at the attachment point, the greater the resistance to shattering.



## ACKNOWLEDGMENTS

Thanks are due to Mr. J. D. Davidson, Assistant Superintendent, Experimental Farm, Indian Head, Sask., for carrying on a special shattering test in 1941 and in accumulating considerable data in connection with this problem. The authors are also grateful to Mr. P. R. Cowan, of this Division, for his assistance with the photographic work.

# A PRELIMINARY REPORT ON THE CLIMATOLOGY OF THE WHEAT STEM SAWFLY (*CEPHUS CINCTUS* NORT.) ON THE CANADIAN PRAIRIES[1]

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The wheat stem sawfly (*Cephus cinctus* Nort.) was first reared by Albert Kaebels in 1890 (1) from larvae mining in the stems of native grasses near Alameda, California. The adults were described the next year as *Cephus occidentalis* by Riley and Marlatt who made the suggestion that, "The economic importance of this species arises from the fact that it may be expected at any time to abandon its natural food-plant in favour of the small grains, on which it can doubtless successfully develop." In 1895, Dr. Fletcher, then Dominion Entomologist, collected specimens at Indian Head, Saskatchewan, and reported that wheat stems containing *Cephus* larvae had been sent to him from Souris, Manitoba. Since that time the insect has spread from the southwestern corner of Manitoba, across Saskatchewan and into Alberta. This spread appears to have been very gradual and has followed a definite northwesterly direction.

The prophetic statement of Messrs. Riley and Marlatt has indeed come true not only as regards sections of the United States but also as regards our Canadian prairies. The present area of infestation in Canada has suffered severe losses to wheat during the last thirty years.

The study of the wheat stem sawfly has indicated that reported crop losses are not always due to an unusual increase in numbers of the insect. With comparatively few of the insects present some fields of wheat may show a severe loss while the majority are free of infestation. On the other hand, an enormous outbreak over a widespread area may result in a small and unnoticed loss to every field of grain and a report of little or no damage may be issued for the season.

In order to study the effect of weather on the wheat stem sawfly it is first necessary to make sure that reports of outbreaks actually denote an increase in the numbers of sawflies. Such reports are not plentiful and the data on which this paper is based include only such definite information.

## LIFE HISTORY

The life history of the wheat stem sawfly has been published many times and need only be briefly reviewed here. The adults begin to emerge about the middle of June and usually have all disappeared by the second week in July.

Oviposition in suitable grass or grain stems is general during this time and the eggs hatch in about 8 days. The larvae spend the summer mining up and down the stems. When the plants begin to mature the larvae move to the lower end of the stems, girdle them from the inside about an

[1] Contribution No. 2341, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada. Presented at the World's Grain Exhibition and Conference, Regina, Saskatchewan, 1933.
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inch above the soil surface and spin a silken cocoon about the full length of the remaining stub. The winter is spent in the cocoons below the surface. When the soil temperature rises in the spring, the larvae become active and move freely up and down the stubs.

Pupation takes place in the cocoons during the latter part of May and early June. The pupal period lasts from 10 to 21 days depending on the temperature and moisture content of the soil. A wet cold period may delay emergence several days while a period of high temperature may hasten it.

## HABITS AND REACTIONS

The emergence of adults coincides with certain events in the development of native grasses. When *Agropyron smithii* is beginning to head out, the first adult sawflies appear. At this time the majority of the *Agropyron* stems are sufficiently developed so that some portion of the stem is hollow and suitable for oviposition. Within a few hours after emerging, the female sawflies seek out such stems and begin laying eggs in the hollow portion.

Adult activity usually takes place when the sun is shining and the temperature is above 63° F. Activity ceases instantly when the sun is obscured behind a cloud or when a heavy wind is blowing. When not active the adults rest, usually head downwards, on the stems or leaves. Because of their position when at rest, a heavy rain will invariably force water under the wings and subsequent activity is delayed until they have dried the wings. A driving rain or hail undoubtedly destroys some of the adults and a prolonged wet period seems to have some effect in reducing their numbers.

The female makes a careful examination of a stem before ovipositing in it. If there is not sufficient hollow stem she moves to another until a suitable one is found. This results in the majority of eggs being laid in the strongest and best developed stems available. When the grass or grain development is poor and uneven these well developed stems will receive most of the eggs. In this connection Ainslee (1) has stated that in the spring of 1917 when weather conditions in North Dakota were such that the growth of grasses and grains was greatly hindered, odd stems of *Bromus* were found to be filled with eggs and stems of spring wheat that had barely begun to joint contained 3 or 4 eggs each. This has been found to be true many times in the investigations carried on in Manitoba and Alberta, such stems being the best available locations for oviposition.

Most publications on the wheat stem sawfly refer to the fact that the adults are weak fliers and do not travel any greater distance than is necessary in searching for suitable stems for oviposition. Since the flight activities are usually confined to the lower air levels and cease abruptly when any wind is present, the migration of the species is very slow. Thus it is that in an infested area local infestation will increase rapidly in favourable seasons while the spread to new areas is more liable to be a slow process and largely governed by the distance the adults must fly to find an abundance of stems suitable for oviposition.

When the eggs begin to hatch, the initial food of the first larvae appears to be the other eggs in the same internode followed by the eggs and larvae in the rest of the stem. The dissection of the infested stems early in the

season usually reveals the presence of 1 larva and the remains of several eggs and even other larvae, indicating that but 1 egg per stem can be expected to develop to a mature insect.

As the larvae develop they feed up and down the inside of the stems. This feeding destroys some of the food passages of the plant and at times a stem is so completely girdled that the head dies. When the plant is growing very rapidly and developing a rank growth, this feeding liberates sap into the interior of the stem which is detrimental to the sawfly larva. If sufficient sap escapes the larva is apparently drowned, but with small amounts it may possibly be a factor in promoting bacterial or fungus diseases. The determination of the presence of disease is very difficult as the finding of a dead larva covered with fungus may only indicate a saprophytic growth on a drowned larva.

## EFFECT OF WEATHER ON THE DEVELOPMENT AND SURVIVAL OF THE SAWFLY

There are apparently few periods in the life history of the sawfly where weather has a direct effect on the insect. Cold wet weather in May, undoubtedly retards pupation and emergence. Observations and laboratory experiments have shown that some pupae are killed under such conditions. In contrast to this, many larvae and pupae were killed in exposed stubble by the excessively dry and hot May of 1928. These observations coupled with laboratory experiments indicate that normal pupation and emergence requires some moisture and a favourable temperature, but that freezing or a dry soil surface temperature of over 100° F. may be fatal to larvae and pupae in exposed stubble.

When the adults have emerged their activities are confined to calm periods of bright sunshine with the temperature between 64° and 90° F. A cold, rainy June with considerable wind and cloudy weather reduces the adult activity and undoubtedly kills many of them. Sweepings made after a rain do not yield as many adult sawflies as did those made previously, even though apparently normal activity has been resumed at the time the sweepings are made.

Criddle (4) suggests that dry weather may indirectly affect the development of the sawfly because it retards the development of the flowering stems. Severe drought conditions such as were experienced in southern Manitoba in 1914, caused a premature ripening of the wheat which killed a number of the larvae and seriously stunted many more. Later Criddle (3) reports that the sawfly increases in the drier areas of Manitoba in the drier years but it almost disappeared in the wet years. These statements appear to be contradictory but a dry season which may be favourable for sawfly increase, may produce some crops which are a complete failure because of the poor cultural practices that are used. During the season of 1929 there was a striking example of this in the Drumheller district of Alberta. An area of stubbled-in crop made an early start but was severely burned in July and headed out when 8 inches high. Adjoining it was a crop grown on land that was summer-fallowed the previous season. This crop suffered very little. The sawflies matured and cut the stems in both crops but those in the burned area were apparently smaller. In addition, only 40.3% of the larvae cut the stems in the poor crop while 72.8% cut

the stems in the good crop. These figures indicate that the dry conditions as they affect the host plant are an important indirect factor in the development of sawfly larvae.

A very wet season which produces a rapid and rank growth in wheat appears to be decidedly unfavourable for sawfly larval development. Many larvae are found in the stems apparently drowned in the sap. During the season of 1928 in the Drumheller section of Alberta the mortality from this cause varied from 30% to 50%. Stubbled-in crops which made a poorer growth than those grown on summer-fallowed land showed a generally lower percentage of drowned larvae but still within the limits as stated. This variation under the different methods of cropping is caused by the extra moisture supply which is available for the crop grown on summer-fallowed land and which is responsible for a ranker growth than would be found in the crops grown on stubble of the previous year. Thus the rank growth of a wet season producing plants with a greater sap flow may not only retard the development of the sawfly larvae but may even destroy them.

Criddle (4) states that, "The ideal conditions for development would be a moist spring, a dry, sunny June, and sufficient moisture during July to enable the full development of grasses or grains." In correspondence with Criddle regarding Manitoba conditions and King[3] concerning Saskatchewan, they both agree that a wet July is decidedly detrimental to the development of sawfly larvae. This condition appears to hold in a number of cases and a wet July usually indicates a decreased infestation the next year. There are a few striking examples where the reverse is true and the question of July rainfall will therefore be more thoroughly discussed later.

There are other factors which must be considered before an accurate statement can be made concerning the most favourable weather conditions for sawfly increase. Observations have shown that excessive drought conditions are as detrimental as excessive moisture. These terms are relative and in many cases will only apply to individual fields. For the most part only moisture recognized as precipitation has been considered. Future work must consider the soil moisture and the moisture storing capacity of the soil.

The loss of moisture due to drainage and evaporation in a sandy soil such as that at Treesbank, Manitoba is greater than that of the soil of Saskatoon, Saskatchewan which contains more clay. On the other hand, the heavy "gumbo" (clay-loam) soil of the Drumheller district in Alberta absorbs moisture readily and permits of very little loss by drainage or evaporation. Thus any statement concerning rainfall and plant development must consider the type of soil. This accounts for a particular season causing a crop failure in one area when a duplicate of that season might produce a good crop in a district with a different type of soil. The reaction of wind and temperature on the different soils must be considered as these affect the moisture content and the host plant development. Some soils will bake with a solid surface crust when a period of heavy rainfall is followed by high temperature, and this crust practically prevents surface

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evaporation either with high temperature or heavy winds. Other soils form a loose crust which retards evaporation but is readily broken up by wind and the moist soil below is exposed.

There is one point where weather is an indirect factor in controlling the actual decrease or increase of the sawfly. This concerns the development of grasses and grains in the spring. Field studies correlating the emergence of adult sawflies with grass development have shown that when the first heads appear on native *Agropyron* the sawflies begin to emerge. The height of emergence and the maximum oviposition coincides with the heading out of 25% of the *Agropyron* flowering stems. Ainslee (1) states that the females never choose stems for oviposition that have put forth a head. This certainly is not true in Alberta as these stems appear to be much preferred, apparently because of the extent of the hollow stem that is present. If there are only a few such stems, they will receive the bulk of the eggs laid. It is rather interesting to note that these stems may receive eggs late in the oviposition period even though a well developed larva is present in each one. The result of such a condition is that many of the eggs laid are destroyed by the sawfly larvae. During the season of 1927 when seeded grain was slow in developing, a large number of stems were dissected at the end of the second week of the oviposition period. Not all the stems contained eggs, but those that did averaged 7 eggs per stem. This meant that the uneven development of the host plant had been responsible for the destruction of 6 out of 7 potential larvae by cannibalism due to egg concentration in available host plants. Had the grass and grain developed evenly the eggs would have been distributed among a larger number of stems and the resulting destruction of eggs would have been relatively less.

## WEATHER CONDITIONS FAVOURABLE FOR SAWFLY INCREASE

The ideal conditions for sawfly increase can be summed up from laboratory and field investigations as follows:

(1) A fairly wet fall to provide a moisture reserve for the starting of grass and grain in the spring.

(2) Either a mild winter or one with sufficient snow to protect the larvae and host plants from too severe conditions and enable them to make a strong growth in the spring.

(3) A warm moist May without temperature extremes, which will develop an even stand of host plants and allow maximum emergence.

(4) A sunny June with sufficient rainfall to produce rapid plant growth and not enough to unduly restrict adult activity.

(5) A July with sufficient moisture and high enough temperature to produce a steady plant growth without the plant becoming rank—to insure even and maximum larval development and no larval destruction through sap drowning.

These conditions are somewhat vague as they do not include definite values. To reduce these factors to a workable basis it is necessary first to determine what shall constitute a definite year of weather influence. The weather apparently affects the sawfly more through its influence on the

host plants than in a direct way. In general the agronomists consider a crop year over the prairie region as starting with the first of August. This is based on the fact that moisture received after that date is of more value to the crop of the next season than it is to the crop about to be harvested. Starting the year at August also brings all the factors which directly affect the sawfly into the same year with the conditions which indirectly affect it.

Having accepted this basis, the weather records for the Canadian prairies were studied in connection with known increases of sawfly population irrespective of the amount of actual damage done. Only authentic records of known increase have been considered, and while these are not plentiful the results should be more accurate than if uncertain data were used. For the purpose of this paper a "season" of sawfly increase is a particular year at a particular point. The fact that a marked sawfly increase occurred in the same year at two different points does not mean that it is the same climatic "season" since the amount of rainfall, the mean temperature and soil conditions vary to such an extent that the actual conditions may be as totally different as if they occurred in two different years.

Ten seasons of marked sawfly increase were chosen from reports of localities scattered throughout the infested areas as follows:

Treesbank, Manitoba, 1907, 1914, 1918, 1921 and 1922.
Saskatoon, Saskatchewan, 1923.
Swift Current, Saskatchewan, 1926.
Three Hills, Alberta, 1926.
Hanna, Alberta, 1926.
Medicine Hat, Alberta, 1927.

There are other years at these and other points where increase in sawflies is known to have occurred but these ten represent ideal outbreaks. The results and conclusions presuppose that the year ending July 31 which preceded each of these outbreaks approached optimum conditions for the sawfly. The precipitation and temperature records for these preceding years were tabulated as shown in Table 1.

Each of these ten years it is presumed contains the essential factors favourable for the development of the sawfly in that locality and the average of these ten years should represent an index of optimum conditions. A study of this average in correlation with the ideal conditions for sawfly increase, as previously enumerated, shows the fall season to be fairly wet followed by a cold winter with an even snow distribution and a gradual approach of spring. May has sufficient moisture, with the help of the fall reserve, to produce an even growth of host plants and the temperature is high enough to hasten this growth. June does not carry excessive moisture and has a high temperature which indicates considerable sunshine to promote adult activity while July is somewhat drier and hot enough to bring the host plants to seasonable maturity.

If the individual years are compared with the average and with each other there seems to be a wide range of dissimilarity. This is evidenced in a month to month examination as well as in the total amount of rainfall for the year. Much of this can probably be fully explained after a study of the soil types and their ability to retain moisture has been made. It is rather interesting to note that the two locations which have a sandy soil,

TABLE 1.—MONTHLY MEAN TEMPERATURE AND PRECIPITATION RECORDS FOR THE 12 MONTHS' PERIOD ENDING JULY 31, PRECEDING SEASONS OF SAWFLY ABUNDANCE

| Place | Treesbank | | | | | | | | | | Threehills | | Hanna | | Medicine Hat | | Saskatoon | | Swift Current | | Average | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1906 | | 1913 | | 1917 | | 1920 | | 1921 | | 1925 | | 1925 | | 1926 | | 1922 | | 1925 | | | |
| | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. |
| Aug. | 67 | 1.67 | 62 | 1.10 | 65 | 1.57 | 67 | 1.29 | 69 | 3.50 | 58 | 1.27 | 59 | 2.80 | 66 | 1.47 | 62 | .62 | 62 | 2.48 | 63 | 1.84 |
| Sept. | 58 | 2.56 | 51 | 4.26 | 54 | 1.72 | 55 | 1.69 | 58 | 2.29 | 51 | .80 | 52 | 2.28 | 54 | 3.25 | 51 | 2.98 | 55 | .65 | 54 | 2.25 |
| Oct. | 38 | .70 | 43 | .67 | 37 | 2.74 | 31 | 1.83 | 47 | 1.14 | 41 | 1.40 | 43 | 1.26 | 37 | .29 | 43 | .36 | 46 | 2.76 | 41 | 1.31 |
| Nov. | 28 | .50 | 29 | .26 | 26 | .36 | 11 | 1.16 | 26 | 1.21 | 19 | .35 | 21 | .40 | 33 | .30 | 16 | 1.52 | 23 | .98 | 23 | .70 |
| Dec. | 13 | .52 | 12 | 1.09 | 1 | 1.23 | 3 | .56 | 9 | .71 | 2 | .32 | 2 | 1.50 | 27 | .53 | 7 | .45 | 5 | .93 | 8 | .78 |
| Jan. | 7 | 1.12 | 6 | 1.08 | 7 | 1.79 | 5 | .98 | 7 | .76 | 5 | .20 | 6 | .40 | 24 | .62 | 0 | .50 | 10 | .87 | 5 | .83 |
| Feb. | 3 | .12 | 1 | .90 | 5 | .98 | 8 | .89 | 11 | 1.46 | 7 | .58 | 8 | .30 | 28 | .25 | 9 | .53 | 16 | .22 | 8 | .62 |
| Mar. | 17 | .67 | 10 | .97 | 21 | .37 | 17 | .71 | 17 | 1.12 | 20 | .47 | 19 | .20 | 37 | .27 | 16 | .85 | 24 | .91 | 20 | .65 |
| April | 47 | .92 | 47 | .30 | 34 | 1.37 | 28 | .38 | 36 | 1.65 | 42 | 1.38 | 42 | 3.01 | 48 | .32 | 38 | .37 | 45 | 2.38 | 41 | 1.21 |
| May | 49 | 3.00 | 51 | 1.09 | 50 | .10 | 54 | .68 | 53 | 1.77 | 51 | 1.77 | 52 | .64 | 59 | 1.65 | 54 | 2.09 | 54 | .85 | 53 | 1.36 |
| June | 65 | 2.53 | 66 | 2.64 | 59 | 1.91 | 62 | 3.68 | 68 | 2.95 | 58 | 1.74 | 61 | 1.98 | 64 | 1.14 | 62 | 1.28 | 60 | 1.56 | 62 | 2.14 |
| July | 70 | 1.21 | 64 | 2.26 | 70 | 1.27 | 66 | 2.46 | 72 | .89 | 62 | 1.99 | 63 | 3.63 | 63 | 2.47 | 64 | .79 | 67 | 1.29 | 66 | 1.86 |
| Total pptn. | | 15.52 | | 16.62 | | 15.41 | | 16.22 | | 19.45 | | 12.27 | | 18.50 | | 12.56 | | 11.98 | | 13.88 | | 15.55 |

i.e. Treesbank and Hanna, also had the highest yearly precipitation preceding outbreaks, while that of the areas of heavier soil was much lower. In seven of the ten seasons the July rainfall was less than that of June, but at Hanna and Medicine Hat it was so much higher than June that some explanation appears necessary.

The fall moisture was evidently sufficient to create an excellent reserve in the soil since there were over 6 inches of rain before the first of November at Hanna and over 5 at Medicine Hat. The coldest part of the winter was accompanied by fairly heavy snow at Hanna while Medicine Hat had a milder winter. The host plants at both places made a good start in May on the reserve moisture of the fall combined with that of April. June was apparently ideal from the standpoint of adult activity and the heavier precipitation of July was necessary to produce strong plant growth and prevent drought conditions resulting from the smaller amount of May and June precipitation. This indicates that the accumulated moisture in the soil during the three months' growing period was only sufficient to produce a normal and healthy plant growth and that the apparently excessive moisture of July was not actually sufficient to produce the rank stem so detrimental to sawfly larvae as would have been the case had May and June been wetter. Thus the precipitation and temperature of any one month cannot be considered as directly or indirectly influencing sawfly increase while conditions prevailing in the previous months are disregarded.

## WEATHER CONDITIONS UNFAVOURABLE FOR SAWFLY INCREASE

There are apparently two sets of conditions which are unfavourable for sawfly development. One of these is a "wet year" and the other is extreme drought conditions. These conditions not only affect the yearly fluctuations throughout the present area of infestation but are apparently limiting climatic factors in the spread of the insect into new territory. Since a "wet year" is the most common controlling factor it will be discussed first.

Ten seasons showing a marked decrease in sawfly abundance were taken from reports of the same localities as used in the discussion on sawfly increase. These seasons were picked following a heavy outbreak as near as possible and are as follows:

Treesbank, Manitoba, 1923, 1924, 1925.
Saskatoon, Saskatchewan, 1924.
Swift Current, Saskatchewan, 1927, 1928.
Three Hills, Alberta, 1927, 1928.
Hanna, Alberta, 1927.
Medicine Hat, Alberta, 1928.

The temperature and precipitation records of these seasons are shown in Table 2.

As the records of years preceding increase contained certain conditions favourable to the sawfly development, so each of these years and the average should contain conditions which are unfavourable. The average of these ten years shows less moisture in the fall and winter, which means a shortage

TABLE 2.—MONTHLY MEAN TEMPERATURE AND TOTAL PRECIPITATION RECORDS FOR "WET YEARS" ENDING JULY 31, PRECEDING SEASONS OF KNOWN SAWFLY DECREASE

| Place | Treesbank | | | | | | Saskatoon | | Swift Current | | | | Three Hills | | | | Hanna | | Medicine Hat | | Average | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1922 | | 1923 | | 1924 | | 1923 | | 1926 | | 1927 | | 1926 | | 1927 | | 1926 | | 1927 | | | |
| | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. |
| Aug. | 66 | 2.65 | 68 | 2.97 | 61 | 1.79 | 65 | 3.87 | 64 | 1.79 | 69 | 2.49 | 58 | .98 | 64 | 1.88 | 59 | .92 | 73 | .56 | 65 | 1.99 |
| Sept. | 55 | 5.14 | 59 | 3.05 | 58 | .88 | 56 | .77 | 53 | 2.68 | 45 | 1.09 | 48 | 2.73 | 41 | 3.16 | 49 | .99 | 48 | 1.50 | 51 | 2.20 |
| Oct. | 45 | .55 | 43 | .34 | 43 | 1.09 | 40 | .86 | 31 | .90 | 42 | .62 | 31 | .43 | 41 | .16 | 31 | .32 | 48 | .02 | 39 | .53 |
| Nov. | 17 | .85 | 28 | .72 | 34 | 1.06 | 26 | .13 | 29 | .15 | 22 | .77 | 26 | .23 | 19 | 1.25 | 27 | .45 | 28 | .95 | 26 | .64 |
| Dec. | 12 | .30 | 1 | 1.91 | 13 | .50 | 16 | .85 | 21 | .23 | 11 | .40 | 23 | .60 | 7 | .30 | 21 | 1.30 | 16 | 2.15 | 12 | .85 |
| Jan. | 1 | .70 | 1 | 1.38 | 4 | 1.09 | 1 | .37 | 19 | 1.10 | 14 | .48 | 19 | .42 | 6 | .18 | 18 | .90 | 16 | .16 | 10 | .68 |
| Feb. | 2 | .97 | 1 | 1.04 | 12 | .68 | 2 | .62 | 21 | .45 | 12 | 1.10 | 18 | 1.04 | 6 | .55 | 18 | 1.00 | 16 | 4.9 | 11 | .79 |
| Mar. | 24 | 1.29 | 7 | 1.36 | 22 | .58 | 11 | .80 | 30 | .31 | 27 | 1.42 | 32 | .51 | 21 | .93 | 26 | .50 | 33 | 1.10 | 23 | .88 |
| April | 42 | 1.04 | 33 | 1.68 | 36 | 5.10 | 36 | .69 | 44 | .13 | 40 | 1.16 | 42 | .08 | 37 | .75 | 40 | .36 | 42 | 1.60 | 42 | 1.26 |
| May | 56 | 2.81 | 52 | 1.60 | 46 | .35 | 52 | 1.65 | 56 | 2.65 | 47 | 6.58 | 51 | .62 | 45 | 2.25 | 48 | 1.66 | 50 | 5.30 | 50 | 2.55 |
| June | 65 | 2.28 | 66 | 3.23 | 58 | 1.93 | 62 | 5.11 | 58 | 2.33 | 61 | 1.11 | 56 | 4.04 | 57 | 2.50 | 56 | 3.69 | 63 | 1.31 | 60 | 2.75 |
| July | 65 | 3.19 | 70 | 3.63 | 65 | 4.95 | 66 | 5.37 | 62 | 3.54 | 65 | 3.47 | 57 | 4.07 | 61 | 2.54 | 63 | 3.00 | 68 | 5.43 | 64 | 3.92 |
| Total pptn. | | 19.87 | | 22.91 | | 20.99 | | 21.09 | | 16.26 | | 20.69 | | 15.75 | | 16.45 | | 15.09 | | 20.48 | | 19.04 |

of reserve moisture for promoting spring growth, with a higher winter temperature indicating frequent thaws and freezes. Periods of warm weather in the winter followed by severe cold are apt to start plant activity and seriously injure the plants with the freezing that follows. This would tend to cause a more uneven development of host plants early in the season with a subsequent concentration of eggs in fewer stems. Such a concentration means a reduction in the ratio between eggs laid and larvae maturing. May and June are both fairly wet with slightly lower temperatures which would cause a reduction in the number of pupae emerging as well as the activity and number of adults surviving. July has excessive moisture following that of the two previous months and insures a rank and succulent stem in which larvae are apt to be drowned. The average yearly precipitation is higher in the unfavourable years and most of this increase occurs in the three critical months of May, June and July.

A study of the individual years shows that in most cases the fall is drier than it is in favourable years. Those years in which May rainfall and temperature are favourable for pupal development, contain either a very wet April or a very wet June and in all of them July is wetter than the average favourable conditions. While one or two of the critical summer months may be favourable or approach the favourable conditions for sawfly development and increase, the combined conditions are distinctly adverse.

The data on dry conditions producing a decrease in sawfly population the next season is very meagre. There are districts within the main area of infestation where the sawfly is seldom seen and then only in years of more than average precipitation. This fact has led to the supposition that some climatic factor is largely responsible for this condition since no other tangible barrier exists to block these areas out from the surrounding infestation. In order to arrive at a conclusion regarding the effect of a dry year on the development of the sawfly the average climate of six places where sawfly is generally present but rarely increases were studied. These are the averages shown in Table 3.

TABLE 3.—THE AVERAGE CLIMATES OF SIX LOCATIONS WITHIN THE AREA OF SAWFLY INFESTATION WHERE OUTBREAKS ONLY OCCUR FOLLOWING WET YEARS

| Place | Alberta | | | | | | | | | | Saskatchewan | | Average | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bow Island | | Brooks | | Empress | | Grassy Lake | | Prospy | | Govenlock | | | |
| | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. | Temp. | Pptn. | Temp. | Ptpn. | Temp. | Pptn. | Temp. | Pptn. |
| Aug. | 64 | 1.23 | 61 | 1.77 | 66 | 2.10 | 64 | 1.77 | 61 | .98 | 64 | 1.15 | 63 | 1.48 |
| Sept. | 55 | 1.22 | 51 | .80 | 52 | .65 | 55 | 1.13 | 51 | .78 | 54 | 1.08 | 53 | .94 |
| Oct. | 46 | .44 | 40 | .78 | 46 | .40 | 46 | .60 | 42 | .67 | 42 | .46 | 44 | .56 |
| Nov. | 30 | .73 | 23 | .41 | 30 | .30 | 30 | .35 | 25 | .87 | 30 | .21 | 28 | .48 |
| Dec. | 21 | .63 | 17 | .76 | 14 | .75 | 21 | .56 | 18 | .86 | 9 | .61 | 17 | .69 |
| Jan. | 12 | .72 | 7 | .41 | 7 | .55 | 13 | .54 | 9 | 1.18 | 1 | .84 | 8 | .66 |
| Feb. | 16 | .82 | 9 | .51 | 6 | .36 | 17 | .33 | 12 | .89 | 11 | .28 | 12 | .53 |
| Mar. | 27 | .60 | 23 | .58 | 19 | 1.07 | 27 | .40 | 14 | 1.31 | 23 | .45 | 22 | .73 |
| April | 43 | .93 | 42 | .89 | 43 | 1.37 | 43 | .75 | 40 | 1.56 | 40 | .85 | 42 | 1.06 |
| May | 53 | .71 | 51 | 1.23 | 52 | 1.33 | 54 | 1.26 | 49 | 1.60 | 52 | .96 | 52 | 1.18 |
| June | 61 | 2.36 | 58 | 1.47 | 62 | 2.50 | 61 | 1.60 | 58 | 1.74 | 61 | 1.68 | 60 | 1.90 |
| July | 66 | 1.22 | 63 | 1.46 | 62 | 1.28 | 66 | 1.22 | 62 | 1.67 | 70 | 1.46 | 65 | 1.38 |
| Total pptn. | | 11.63 | | 11.07 | | 12.66 | | 10.01 | | 14.02 | | 10.03 | | 11.69 |

The average weather of each of these localities shows a small reserve fall moisture which is barely sufficient to start plant growth in the spring. May conditions are favourable for pupation and emergence, though the uneven plant development would cause a greater concentration of eggs in suitable host plant stems than occurs in the wet years. June is generally favourable for sawfly activity but the weather conditions of July would produce a drought condition which would be decidedly detrimental to normal development of the larvae.

## SUMMARY OF WEATHER CONDITIONS

Comparing the general averages of the three sets of weather conditions as shown in Tables 1, 2 and 3, the dormant period of the sawfly from November 1 to April 30 is almost identical in each. The following is the total precipitation and the mean temperature for each set of conditions:

| Dry | | Favourable | | Wet | |
|---|---|---|---|---|---|
| Total precipitation | Temp. | Total precipitation | Temp. | Total precipitation | Temp. |
| 4.15 in. | 21.5° F. | 4.79 in. | 17.5° F. | 5.10 in. | 21.7° F. |

As there is only a difference of 4.2° F. in mean temperature and .95 inches of precipitation between the highest and lowest records, the average dormant period can hardly be considered as containing important factors governing changes in population.

A comparison of individual months during this period shows a wide variation of conditions from the average for each series of years but the monthly averages for the three conditions are very similar.

The remaining six months of the year are separated into two groups of three months each by the six months' period of dormancy. The fall group consists of August, September and October a period when the larvae are in the stubble and approaching a dormant state. The summer group consists of May, June and July, a period where pupation and emergence, adult activity, and the greatest larval activity and development occur.

The average precipitation and mean temperature for each of the fall months as shown in Tables 1, 2 and 3 is as follows:

| | Dry | | Favourable | | Wet | |
|---|---|---|---|---|---|---|
| | Total precipitation | Temp. | Total precipitation | Temp. | Total precipitation | Temp. |
| Aug. | 1.48 | 63 | 1.84 | 63 | 1.99 | 65 |
| Sept. | .94 | 53 | 2.25 | 54 | 2.20 | 51 |
| Oct. | .56 | 44 | 1.31 | 41 | .53 | 39 |

August is similar in both precipitation and temperature for each set of conditions. September is similar in the favourable seasons and the wet unfavourable seasons, while in the dry unfavourable climate it is much drier. October of the two unfavourable seasons has almost an inch less moisture than the favourable seasons. It would appear that the October moisture is an important factor and yet an examination of Tables 1, 2 and 3 shows that for individual seasons the same October conditions can be found in each. The same is true of the months of August and September.

The monthly average precipitation and mean temperature for each of the summer months as shown in Tables 1, 2 and 3 is as follows:

| | Dry | | Favourable | | Wet | |
|---|---|---|---|---|---|---|
| | Total precipitation | Temp. | Total precipitation | Temp. | Total precipitation | Temp. |
| May | 1.18 | 52 | 1.36 | 53 | 2.55 | 50 |
| June | 1.90 | 60 | 2.14 | 62 | 2.75 | 60 |
| July | 1.38 | 65 | 1.86 | 66 | 3.92 | 64 |

A study of these figures shows that these months in the wet year which is unfavourable for sawfly increase have higher precipitation and slightly lower temperatures than the favourable year, the most outstanding feature being the very heavy July precipitation. The dry climate which is unfavourable for sawfly increase has less precipitation per month than the favourable year. Here again the averages indicate a possible weather correlation with sawfly fluctuation which does not occur in the individual years. For instance, July, 1925, at Hanna, Alberta (see Table 1) had 3.63 inches of precipitation and yet was followed by a heavy sawfly outbreak the next season. An examination of these tables will show years which have monthly precipitation records for each of the months equal to the averages for the different conditions.

It is apparently impossible to correlate any weather conditions of a single month with sawfly fluctuation. It is equally impossible to find a definite correlation between total yearly precipitation and sawfly fluctuation since there are years favourable for increase which have a greater total precipitation than some years which have been classed as wet that preceded a marked decrease.

A careful study of host plant development as well as sawfly activity and development indicates that cumulative moisture is a more important factor than monthly precipitation. The total precipitation for August, September, and October without high evaporating temperatures or low freezing temperatures, constitutes a reserve moisture of importance to spring growth. With the freezing of the ground in November, winter precipitation is inclined to run off instead of materially increasing the reserve. A good fall reserve means that less precipitation is needed in the spring and summer to produce a satisfactory plant growth for sawfly development, but a low fall reserve requires a heavy precipitation throughout the growing period. Such a condition produces uneven growth and usually a very rank growth. A year such as that shown in Table 1, at Hanna, Alberta, 1925, with a good fall reserve of moisture did not require a heavy summer precipitation until July. Coming at this time, after a dry May and June, it was not excessive.

To get the effect of cumulative moisture and find a correlation between weather and sawfly fluctuations, the year has been divided into four periods of three months each, starting with the first of August. The total precipitation and mean temperature for each period can be used as an index of cumulative moisture but until actual soil studies are made this will not be accurate. The average from Tables 1, 2 and 3 show the following indexes of cumulative moisture.

| | Dry | | Favourable | | Wet | |
|---|---|---|---|---|---|---|
| | Precipitation | Temp. | Precipitation | Temp. | Precipitation | Temp. |
| Aug.-Oct. | 3.08 | 59 | 5.36 | 52 | 4.71 | 52 |
| Nov.-Jan. | 1.83 | 18 | 2.31 | 12 | 2.18 | 14 |
| Feb.-April | 2.52 | 25 | 2.71 | 23 | 2.92 | 26 |
| May-July | 4.46 | 59 | 5.38 | 58 | 9.31 | 56 |

The areas of light infestation which are listed under Table 3 representing weather conditions too dry for sawfly increase are not as satisfactory as they would be if actual dry seasons preceding decrease would be used. Unfortunately data for drought conditions throughout the infested area are not available. The areas used have a light soil which would not hold moisture as well as the heavier soils so that a 3.08 inch fall reserve with a mean temperature for the three months of 59° F. would not leave a great reserve for starting spring growth. The summer precipitation of 4.46 inches with a mean temperature of 59° F. would be sufficient to produce a light crop of irregular development.

The column representing the wet season unfavourable for sawfly increase covers all types of soils, and in studying individual years at definite locations the soil type would have to be taken into consideration. The fall moisture of 4.71 inches represents a good reserve and the mean temperature of 52° F. could hardly be considered as causing an excessive evaporation. The summer precipitation of 9.31 inches is certain to produce an excessively rank growth, especially with a mean temperature of 56° F. which probably indicates hot wet weather in July. Even though July be inclined to dry conditions the high temperature with the excessive cumulative moisture would cause a rank plant development.

The conditions favourable for sawfly increase shown by these figures indicates a good fall reserve with medium precipitation and high temperature the following summer. The lower precipitation and higher temperature usually confined to July makes a strong stemmed host plant ready to mature early in August when the larvae are full grown, but not rank enough to drown the larvae inside the stem.

The averages as shown by the figures agree better with individual years as shown in Tables 1, 2 and 3 than do the straight monthly figures. The results can be plotted as "three months' cumulative" hythergraphs.

Figure 1, is a graphic representation of the cumulative index taken from the averages of Table 1. As this represents the average of ten years preceding marked sawfly increase throughout the infested area it is used as a general index of optimum conditions for the sawfly.

Figure 2, is a graphic representation of the cumulative index taken from the averages of Table 2. The years upon which this is based all preceded a marked decrease of the insect. The main differences between the two graphs are the precipitation for the August-October and May-July periods.

Figure 3, is made from the averages of Table 3 and represents the general cumulative index of the average climate of the six points studied. While this does not actually represent years which preceded sawfly decrease

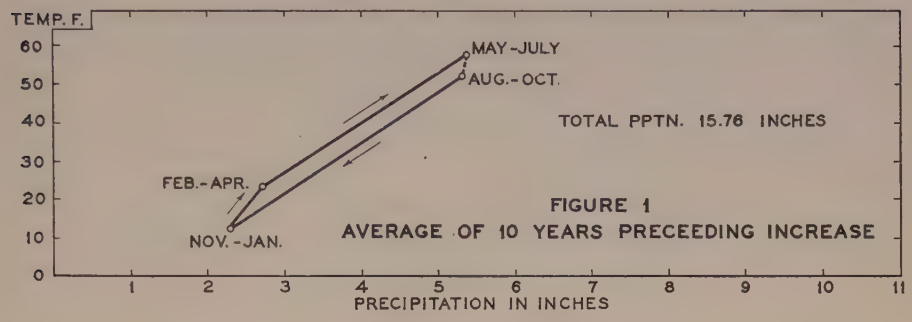


FIGURE 1
AVERAGE OF 10 YEARS PRECEEDING INCREASE

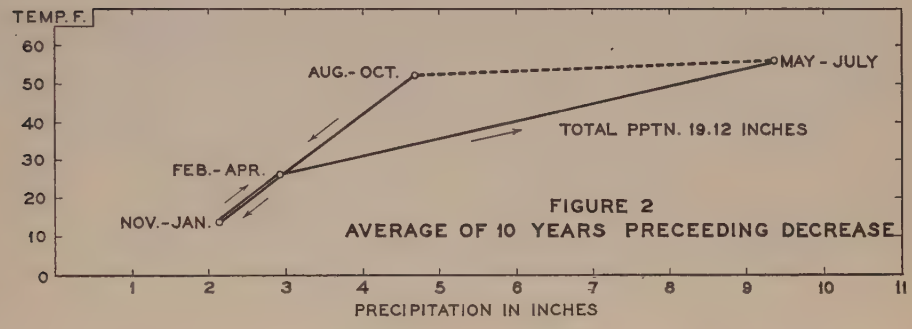


FIGURE 2
AVERAGE OF 10 YEARS PRECEEDING DECREASE

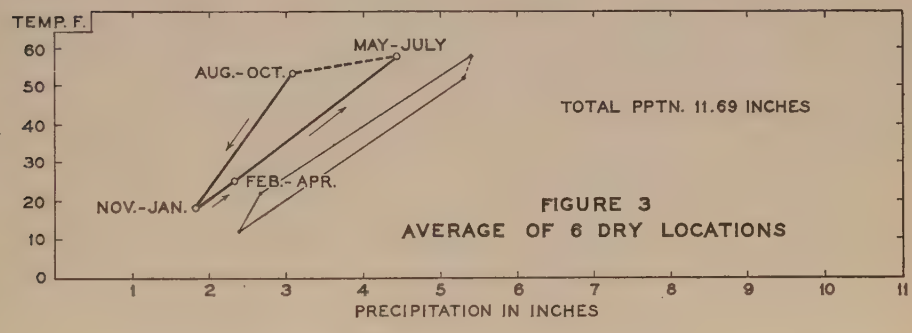


FIGURE 3
AVERAGE OF 6 DRY LOCATIONS

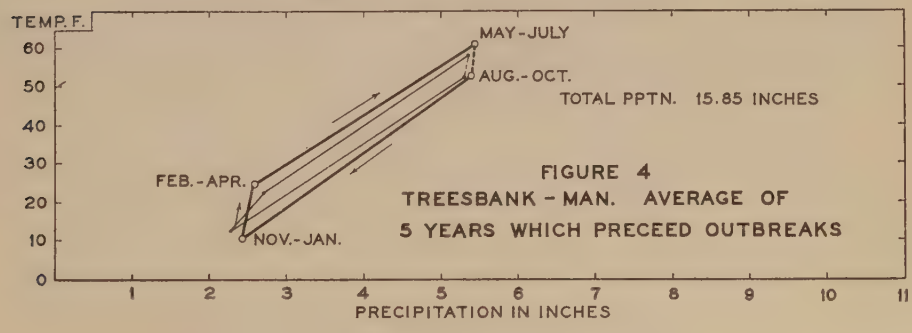


FIGURE 4
TREESBANK - MAN. AVERAGE OF
5 YEARS WHICH PRECEED OUTBREAKS

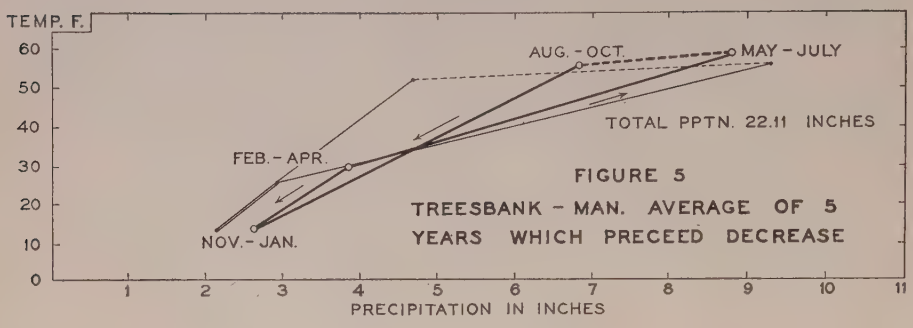


FIGURE 5

TREESBANK - MAN. AVERAGE OF 5 YEARS WHICH PRECEED DECREASE

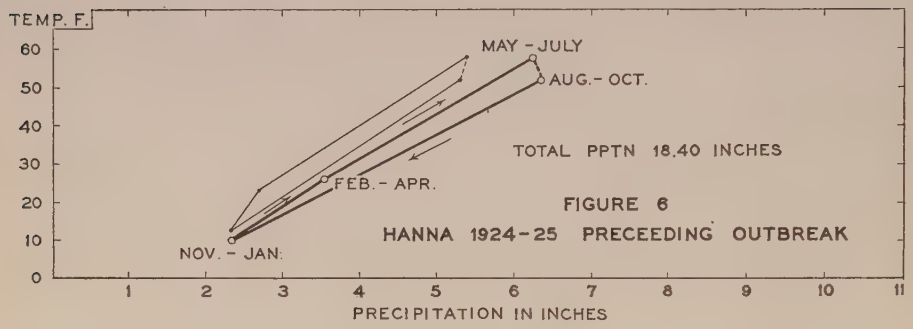


FIGURE 6

HANNA 1924-25 PRECEEDING OUTBREAK

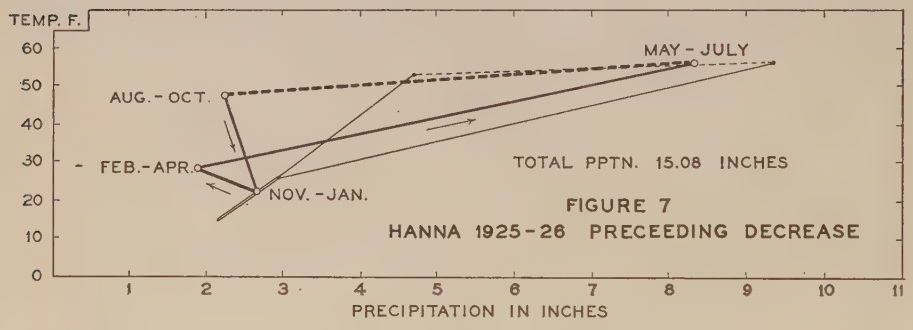


FIGURE 7

HANNA 1925-26 PRECEEDING DECREASE

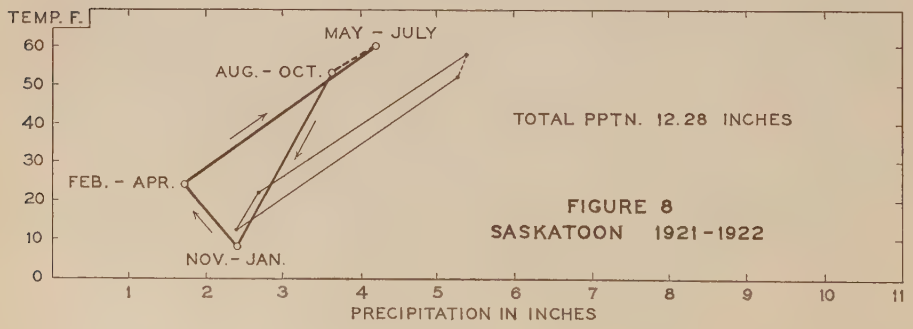


FIGURE 8

SASKATOON 1921-1922

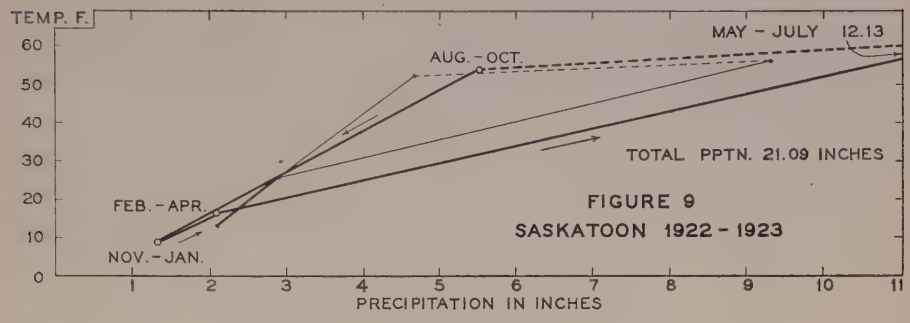


FIGURE 9
SASKATOON 1922 – 1923

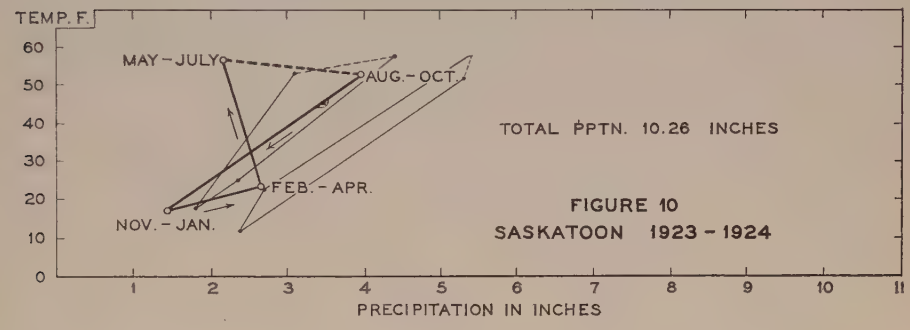


FIGURE 10
SASKATOON 1923 – 1924

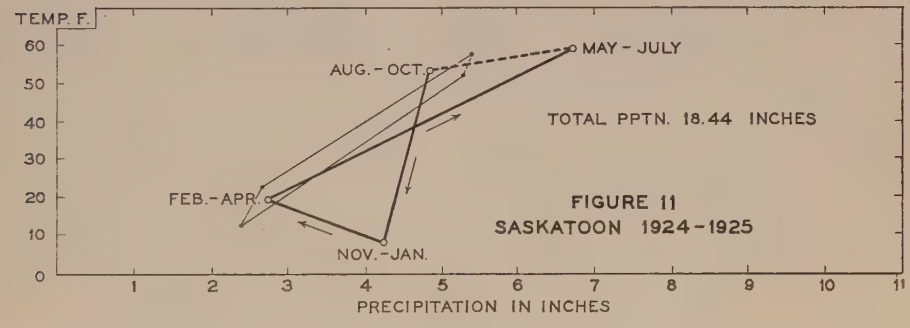


FIGURE 11
SASKATOON 1924 – 1925

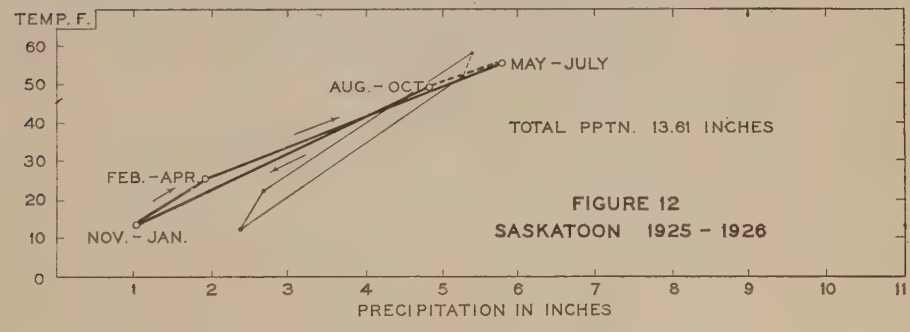


FIGURE 12
SASKATOON 1925 – 1926

because of drought conditions, it does represent conditions under which the sawfly has seldom been troublesome enough to attract attention even though it has been present for several years.

Since these hythergraphs represent average conditions, the weather of any one year can be plotted in the same manner and the result compared for a correlation with sawfly fluctuations.

Figure 4, shows a three months' cumulative hythergraph which is the average of five years preceding serious outbreaks at Treesbank, Manitoba. Figure 5, is the average of five years preceding decrease in populations at the same place. Figures 1 and 2, are shown in fine lines for comparison.

Figure 6, is the three months' cumulative hythergraph for the single year ending July 3, 1925 at Hanna, Alberta, compared with the "optimum index." While both the fall and summer periods have a slightly lower temperature and higher precipitation than the optimum index it is close enough to indicate the increase of sawfly.

Figure 7, is the graphic representation of the following year at Hanna, Alberta (ending July 31, 1926). This hythergraph is compared with Figure 2 in fine lines and here again there is a marked similarity. The dry fall period of 1925 probably was as big a factor in reducing numbers as the excessive moisture of the summer period of 1926. It is interesting to note that the total yearly precipitation represented by Figure 6 is 3.32 inches greater than that of Figure 7 but the seasonal distribution determines the difference between two years in regard to sawfly fluctuation.

K. M. King of the Dominion Entomological Laboratory at Saskatoon has made some very careful studies in regard to sawfly fluctuations in connection with his soil rotation studies. He has very kindly furnished some of his data. This has been correlated with the moisture and temperature studies for this paper. King states that in the season of 1923 sawfly was very abundant in the vicinity of Saskatoon but the excessive moisture of that season caused a very high mortality with a corresponding decrease in infestation in 1924. Another factor appeared in 1924 which would not show in the hythergraphs. This was a severe frost in May after larval activity had been resumed. King records a mortality of 15 to 20% at this time. The season of 1924 was dry and crops amounted to practically nothing. This drought condition should have caused a reduction in numbers in 1925. The next season, 1926 was one of the worst on record in Saskatchewan for sawfly infestation and King stated that a great majority of the larvae apparently entered the winter of 1926 in good condition for the season of 1927.

Figures 8 to 12 show the weather conditions during the period from the end of July 1922 to the end of July 1926, which covers the sawfly fluctuation for the seasons of 1923-27. The year ending July 31, 1922 (Figure 8) was fairly dry but with sufficient fall and summer moisture to produce a fair crop with little effect on the sawfly, even though it approaches the dry conditions as represented by Figure 3. This would produce the numbers present in the season of 1923. The year ending July 31, 1923 (Figure 9) follows closely the hythergraph of a year preceding decrease (Figure 2) except for the abnormally high summer precipitation. This could cut the population to a minimum in 1924 even if the heavy frost of late May in

1924 had not occurred. The year ending July 31, 1924 (Figure 10) was very dry though crops would get a fair start from the excess moisture of 1923. The very dry May-July period of 1924 produced drought conditions which were certainly not favourable for an increase in sawfly abundance. Thus the season of 1925 would not show any increase in population over 1924 but the year ending July 31, 1925 (Figure 11) was favourable for a marked increase in 1926. The fall precipitation with its attendant favourable temperatures was conducive to a good reserve supply of moisture and though the period of November-January was cold, the heavy snow gave ample protection if it was needed. The May-July precipitation and temperature were favourable though there was more moisture than the optimum index. Since this followed a very dry year this extra precipitation may have been necessary to promote favourable growth. The general conditions were nearer the optimum index than they were to the unfavourable and would be expected to produce a marked increase in sawfly population. The year ending July 31, 1926 (Figure 12) was favourable for increase from the standpoint of precipitation. The lower temperature may have affected the development of the sawfly but this is not very probable since the mean for the summer months is only two degrees below the optimum index.

## CLIMATE AND THE DISTRIBUTION OF THE WHEAT STEM SAWFLY

The sawfly has apparently spread very gradually across the Canadian prairies. The map (Figure 13) shows the present area of economic distribution as well as that part of it where the insect is of greatest economic importance. In this latter area the sawfly is always present and outbreaks are frequent. Outside of this but within the area of economic distribution losses have occurred but outbreaks are seldom as frequent or severe.

There are localities within both areas where the insect is known to be very scarce, and a thorough survey would undoubtedly show more of these. As these localities are surrounded by constant infestation it seems probable that the local climate may be a factor preventing the sawfly becoming well established. A considerable area northwest and west of Medicine Hat, Alberta, extending from Youngstown through Brooks (represented by double line on the map) has had little or no trouble. The insect is present in that portion of the area north of the river and on rare occasions has caused small losses. A study of the precipitation map of the Dominion Meteorological Service shows the precipitation of this area to be between 11 and 13 inches annually. The general area of infestation follows roughly the districts having between 13 and 17 inches of precipitation in the heavier soil area and 15 to 19 inches were the soil is sandy. This particular dry area is a light soil district and with the attendant low precipitation it may act as a barrier to the southwestern advance of the sawfly. Except for one or two places the insect has not crossed the Bow River in Alberta. In one locality south of Gleichen the sawfly occurs for six or seven miles south of the river. This is an area of medium light soil with an average yearly precipitation of 15 or more inches. After the Bow River joins the South Saskatchewan the insect has crossed in the vicinity of Medicine Hat and traces have been found to the Montana border as indicated by the dotted area on the map. Essentially a dry section of Alberta this particular strip

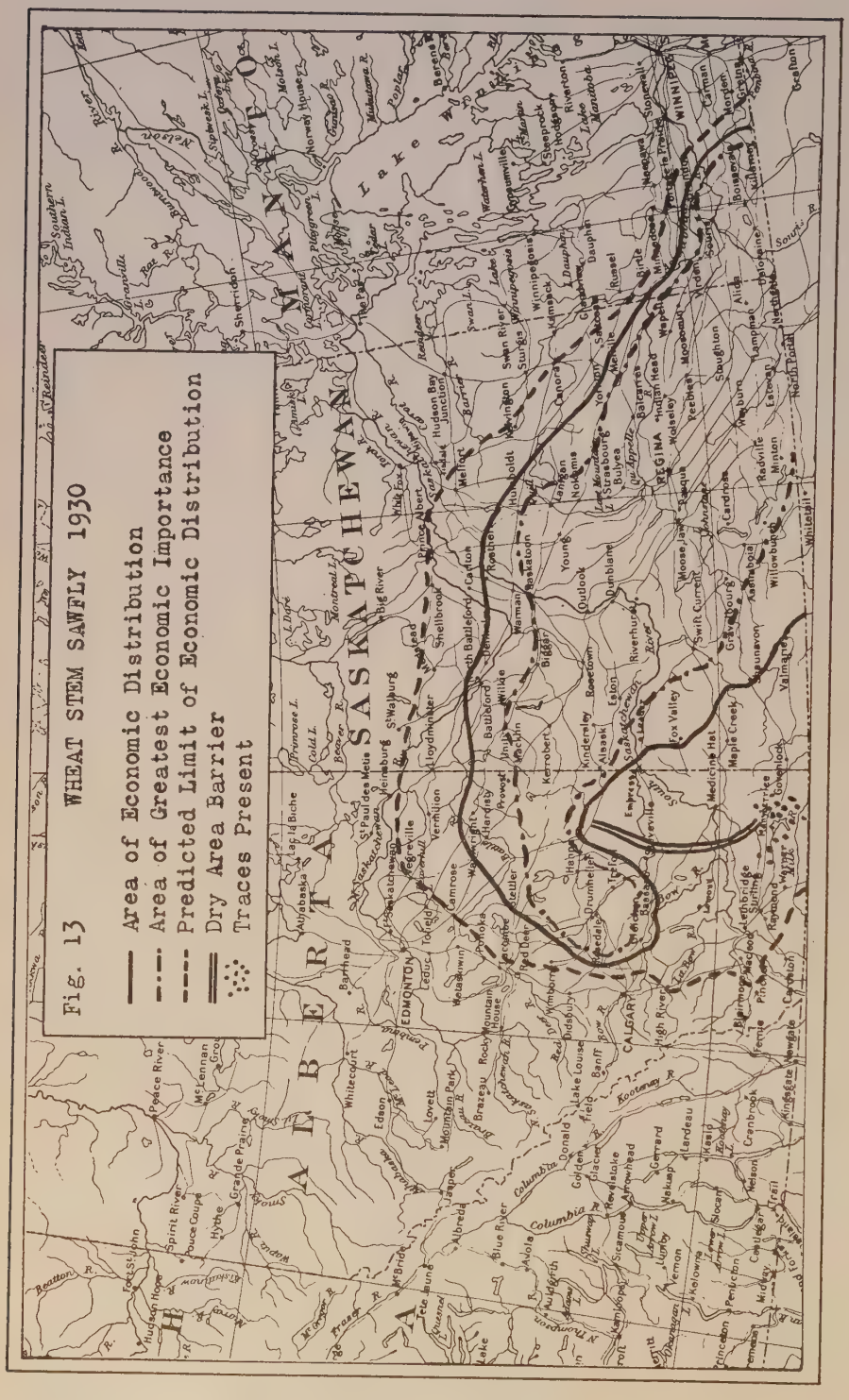
Fig. 13 WHEAT STEM SAWFLY 1930
Area of Economic Distribution
Area of Greatest Economic Importance
Predicted Limit of Economic Distribution
Dry Area Barrier
Traces Present
ALBERTA
SASKATCHEWAN
MANITOBA
Lake Winnipeg
EDMONTON
CALGARY
REGINA
WINNIPEG

FIGURE 13.

is affected by the Cypress Hills and the precipitation here is about 15 inches. There is no doubt that rivers the size of the Bow and South Saskatchewan would act as partial barriers to such a weak-flying insect as the wheat stem sawfly, but its westward migration from the present southeastern infestation in Alberta is apparently much slower because of the dry strip represented by the double line. The eastern migration from this same light infestation may be partially stopped by the excessive precipitation of the Cypress Hills and the dry area south of them at Govenlock, Saskatchewan.

In order to find a correlation between the weather conditions affecting yearly fluctuations and the climate affecting distribution of the sawfly, hythergraphs were made for comparison. The fifteen locations within the area of heaviest infestation which had the longest series of weather records were selected. These records were averaged and plotted as a three months' cumulative hythergraph. Figure 14 shows the result compared with the optimum index as shown in Figure 1. The period of May-July has slightly over 1 inch more precipitation than the optimum index while the fall period has 1 inch less. A year such as is represented in Figure 14 when occurring in a heavy soil area might be too wet for an appreciable increase though occurring in a light soil area it might be ideal. It comes well within the limits of three months' precipitation and temperature as shown in the figures in Table 1 of individual years preceding sawfly increase. Years slightly on the dry side of this average would be so near the optimum index that an outbreak would be expected while a wet year would easily throw this hythergraph into the form of that in Figure 2 which would reduce an outbreak condition.

The limits of the present area where the insect occurs in economic numbers on the Canadian prairies are shown on the map. Thirteen points which have weather records covering several years were chosen as close to this line as possible. The average records were plotted to make the hythergraph as shown in Figure 15. Points within the dry area of southeastern Alberta were purposely omitted from this average because they represent a particular condition not comparable with the area north and west of the present distribution. The hythergraph as shown in Figure 15 represents the average conditions within 60 miles of the present limit of infestation from Claresholm, Alberta, north, east and south to Emerson, Manitoba. The average climate of this surrounding area corresponds closely to the average conditions of the years which, within the area of heaviest infestation, precede a decrease in sawfly population as shown in Figure 2 (indicated on Figure 15). The fall precipitation and temperature compare very closely. The conditions for the period of May-July show a little more than 1 inch less precipitation but well over the lower limit of summer precipitation in individual years as shown in Table 2. It would require a series of years with unusually dry summers to bring the sawfly population up to economic numbers beyond the present area of infestation. On the other hand a series of years with summer precipitation above the average would force the present borders of the infested area back towards the area of greater infestation.

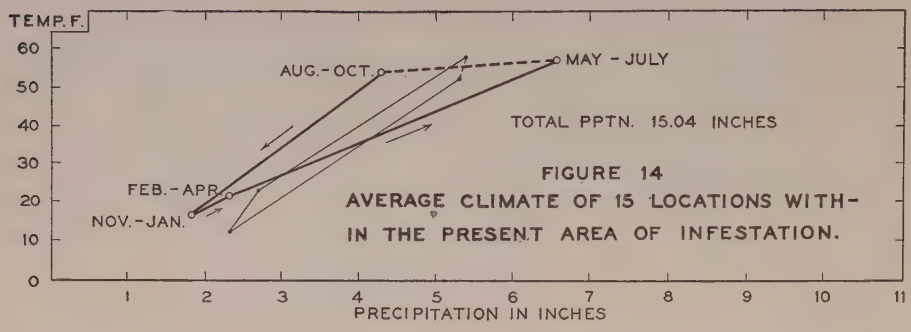


FIGURE 14
AVERAGE CLIMATE OF 15 LOCATIONS WITHIN THE PRESENT AREA OF INFESTATION.

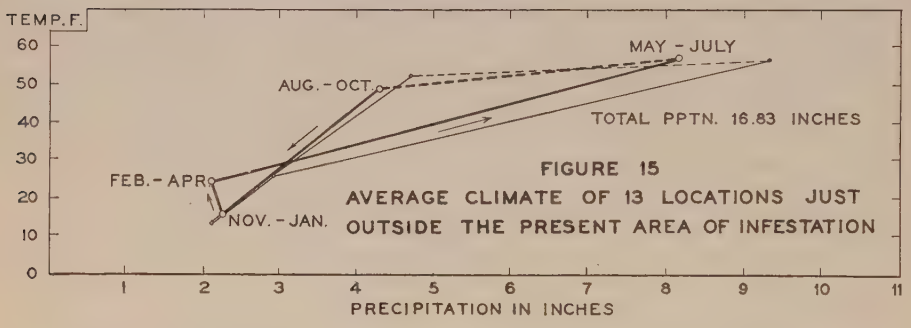


FIGURE 15
AVERAGE CLIMATE OF 13 LOCATIONS JUST OUTSIDE THE PRESENT AREA OF INFESTATION

The average climate of localities within the area of greatest infestation may be unfavourable to sawfly increase and still not be such as to cause a serious reduction in numbers. The result would be a constant infestation subject to an increase of economic importance following a single favourable year. The average climate of Treesbank, Manitoba, as illustrated by Figure 16, is within the lower limits of conditions favourable to the decrease of sawfly population. In this sandy area the May-July precipitation is sufficient to produce a rank growth of the host plants, but the high mean temperature for the period would tend to minimize the cumulative effect of the precipitation. The result would be that in an average year the sawfly population for that district would fluctuate very little.

The average climate of Three Hills, as shown in Figure 17, while approaching the optimum index would have a tendency to cause a decrease in population because the heavy soil and lower mean temperature would increase the cumulative moisture. The small total fall precipitation is not favourable so that the average year in this locality would be more inclined to show a decrease in sawfly population than the average year at Treesbank.

The dry portion of southeastern Alberta presents an entirely different problem. The average climate of six points in this area has already been shown in Figure 3. While the sawfly actually occurs in this district north of the river it has never been of real economic importance. In the southern part of the area indicated by the double line on the map (Figure 13) the insect has not yet been found. It is possible that a few wet years may

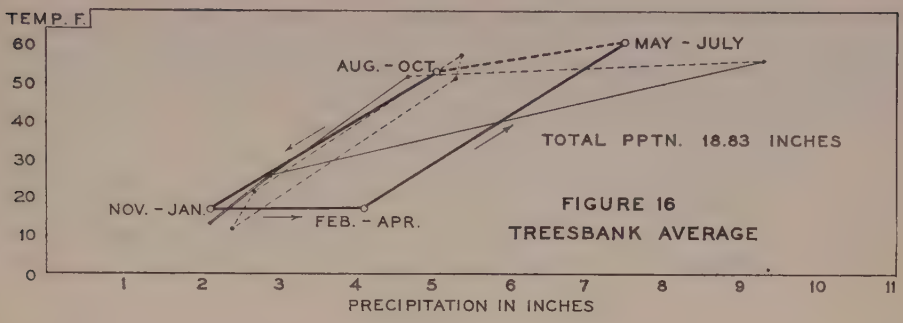


FIGURE 16
TREESBANK AVERAGE

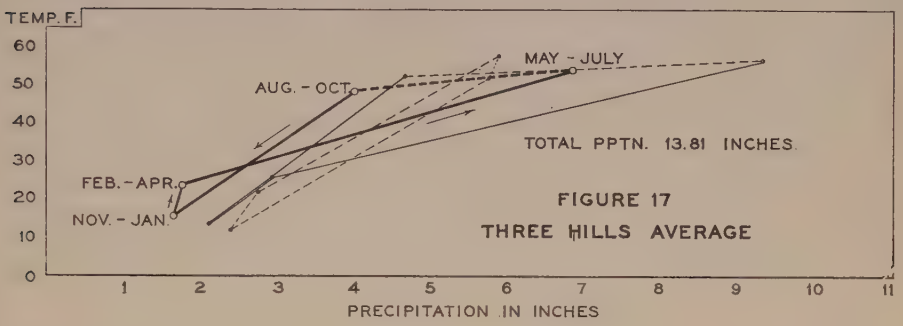


FIGURE 17
THREE HILLS AVERAGE

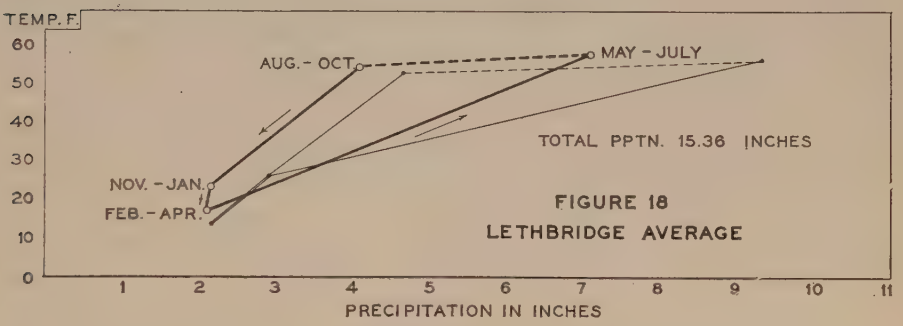


FIGURE 18
LETHBRIDGE AVERAGE

produce conditions whereby the sawfly can gain a foothold here and push the spread westward in the south. The evidence as shown by the fluctuations at Brooks indicates that increase will be very slow and then only after a series of three or four very favourable years.

There is no reason why the sawfly should not spread somewhat farther into the southwest in Alberta and eventually be found in most of the area along the border from Coutts, Alberta to Emerson, Manitoba. The northern limit in Manitoba and Saskatchewan has almost been reached although small isolated localities may be found where the climate would be favourable for outbreaks. The western limit has almost been reached in Alberta north of Calgary. South of Calgary the sawfly should eventually reach the Lethbridge, Macleod and Claresholm area although it does not occur there now. This prediction is based on the average hythergraph of Lethbridge (Figure 18) which is fairly typical of this section of the province. The average year approaches the general average of unfavourable condi-

tions although the insect should be able to exist. A season of just moderately dry conditions during the May-July period would closely approximate the optimum index or at least reach the maximum moisture conditions of individual years as shown in Table 1. The May-July mean temperature is identical with the optimum index.

The large wheat growing section in the Peace River district of Alberta should remain free of economic injury from Western wheat stem sawfly for many years, in spite of the fact that traces of the insect have been found there in native grass. The average climate of that area is not favourable for increase and there is a vast area between there and the present limits of economic infestation which is very unfavourable. Any migration from the present area of infestation through the two or three hundred miles of unfavourable territory would be very slow if not impossible.

## FORECASTING OUTBREAKS OF THE WHEAT STEM SAWFLY

The study of the climatology of the wheat stem sawfly introduces the possibility of forecasting outbreaks of the insect. Before this can be done, many factors and conditions must be considered. An increase in numbers does not necessarily mean increased damage. The former is apparently greatly dependent on the conditions of the previous year while the latter is a direct result of the conditions of the particular season. The infestation in the vicinity of Three Hills, Alberta, was very heavy in the spring of 1926. There was some loss throughout the entire area and in a few cases fields were completely cut by the insect. The next season the numbers were considerably reduced and the infestation though general was fairly light. A period of two weeks' wet weather in the fall prevented the farmers from cutting their grain on time, with the result that every stem containing a healthy sawfly larva was cut before the grain could be harvested. The cut stems were beaten to the ground by the rain and were a total loss. The general loss in the season of 1927 was greater than the previous year even though the sawfly population was considerably less.

The types of soil and their moisture storing capacities must be studied before accurate forecasting can be made. The light soils may receive a heavy precipitation which will drain through and have only a slight effect on the insect or host plants. Some heavy soils clog with a slight amount of rain and the subsequent precipitation runs off. The soil of the Three Hills area is filled with cracks of varying widths running several feet into the ground. Even though the surface soil is saturated with water there is seldom any run-off as the water works into the cracks and builds up a subsoil reserve, not affected by high temperatures.

The detailed study of the meteorological records of years preceding outbreaks shows that the precipitation for the period of August-October varies from 3.47 inches in the heavy soil area to 6.93 in the sandy area. The lowest mean temperature, 50° F., occurred with the lowest fall precipitation which would tend to increase the cumulative moisture. The highest mean temperature for this period was 58° F. and accompanied the highest precipitation; in the light sand soil this would reduce the cumulative moisture and bring it nearer the average.

The May-July precipitation varied from 3.28 inches to 6.74 inches. Both extremes occurred in the sandy soil area with only average mean temperature. The mean temperature varied from 57° to 64° F. The high precipitation followed a fairly dry warm fall and the majority of the spring precipitation occurred in May. This would tend to increase the reserve moisture without seriously handicapping the sawfly development. The low spring precipitation was assisted by a wet fall and heavy winter snowfall so that the cumulative effect would approach the average.

The records preceding decrease in sawfly population have a fall precipitation varying from 2.08 inches to 8.44 inches and a mean temperature variation from 46° F. to 57° F. The heavy fall precipitation was followed by over 8 inches of summer rainfall which would produce very unfavourable conditions for the sawfly. The lightest fall precipitation which would result in uneven host plant development was followed by over 12 inches of early summer rainfall.

The May-July precipitation for years preceding sawfly decrease varied from 7.23 inches to 12.13 inches and the mean temperature for the period varied from 54° to 63° F. The lowest precipitation was accompanied by a very wet cool April, a dry cold May and a warm wet July. While April has not been considered as having very much influence, in this case the precipitation was over 5 inches. This, when followed by a cool May, would have the same cumulative effect as increasing the May precipitation.

A true forecast of sawfly increase or decrease for the Canadian prairies should be based on precipitation, temperature and soil moisture. With the limited data available, the soil moisture factor is eliminated for the present and the forecast is based on precipitation and temperature with consideration for the soil types.

*In heavy soil areas the sawfly population apparently increases when the precipitation during the period of August-October of over 3 inches, accompanied by a mean temperature of between 50° and 58° F., is followed by a May-July precipitation of under 6 inches and a mean temperature of 57° to 64° F.* The lower precipitation in either period must be accompanied by the lower mean temperature. If drought conditions are present there may be a decrease in sawfly population, provided the drought seriously affects the crops grown under all methods of cultivation.

*In the light soil areas the sawfly population apparently increases when an August-October precipitation of over 4 inches, accompanied by a mean temperature of 50° to 58° F., is followed by a May-July precipitation of less than 7 inches accompanied by a mean temperature of 59° to 64° F.* The lower precipitation in either period must be accompanied by the lower mean temperature, and the increase will be more marked if July is the driest of the three summer months. Drought conditions are more apt to be present in the light soil areas, and a precipitation of less than 4 inches during the May-July period accompanied by a high mean temperature may cause a marked decrease in sawfly population.

*The sawfly population apparently decreases whenever the precipitation for the period of August-October of less than 5 inches with a mean temperature of 46° to 57° F. is followed by a May-July period with the precipitation over 7 inches and a mean temperature of 54° to 63° F.* The lower temperature

must accompany the lower precipitation and if the fall precipitation is greater than 5 inches with a correspondingly high mean temperature it must still be followed by a high summer precipitation. This statement of forecasting apparently applies to the different soil types though it is probable that the totals could be lowered for the heavy soil areas with the same result.

Using these figures as a basis, several years have been chosen as showing a marked increase or decrease in sawfly abundance. The verification of the results has borne out the forecasting surprisingly well.

## ACKNOWLEDGMENTS

The assistance of Mr. Norman Criddle[4] of the Dominion Entomological Laboratory at Treesbank, Manitoba, and Mr. K. M. King of the Dominion Entomological Laboratory at Saskatoon, Saskatchewan, made this paper possible. Both have given freely of their observations and unpublished information. Reliable information on weather observations and sawfly fluctuation could not have been obtained from any other sources.

## SUMMARY

The wheat stem sawfly (*Cephus cinctus* Nort.) is a native grass-inhabiting insect which has become a wheat pest of the Canadian prairies.

The adults emerge in June and oviposit in well developed stems of grasses and grains. The larvae spend the summer feeding in the stems. As the plants mature the larvae girdle the stems from the inside just above the soil surface. The stems fall to the ground and the larvae spend the winter in silken cocoons, in the cut stubs. Pupation takes place late in May.

Rainy wet weather in the spring affects the pupation and emergence of adults and a stormy June may kill some adults. The development of a few strong host plants in the spring results in a concentration of eggs in these plants. One larva matures in each stem after destroying all the other eggs and larvae. A fall precipitation which builds up the reserve moisture in the soil and causes an even development of host plants reduces the concentration of eggs and insures a greater number of larvae for the number of eggs laid. Heavy summer precipitation which produces a rank growth in the host plants results in many larvae being drowned in the sap which runs into the hollow stem from the larval feeding cuts.

The weather conditions during the crop year from August 1 to the following July 31 apparently affect the sawfly population for the next season. The two periods of August-October and May-July seem to exert the greatest influence on the host plants and the sawfly, and the influence of weather appears to be more of a cumulative effect of each period rather than the effect of separate months.

Hythergraphs have been constructed on a three months' cumulative basis and used as a basis of discussing weather conditions. These are used in correlating individual seasons and sawfly fluctuation as well as the climate of the prairies and sawfly distribution.

[4] Deceased.

There appears to be a possibility of forecasting sawfly fluctuations with greater accuracy when the present information can be correlated with soil moisture investigations. At present a tentative forecasting can be made based on the precipitation and mean temperature for the periods of August-October and May-July.

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# A BIOLOGICAL METHOD OF DETECTING THE PRESENCE OF FUNGICIDES ON SEEDS[1]

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During the course of some seed studies in which the effect of the fungus, *Helminthosporium sativum*, on germinating wheat seeds was being studied, it was discovered that conidia of this fungus would not germinate near seeds treated with Ceresan. This is an organic mercury dust used on cereal seeds for the control of smut and other fungi. This observation led to the adaptation of this principle for the purpose of testing seed for the presence of Ceresan and, more particularly, for measuring coverage; i.e., the percentage of seeds which received a uniform covering of dust.

## MATERIALS AND METHODS

The following procedure was followed in setting up the test. Agar was poured into Petri dishes, and when cool, it was inoculated by flooding with a heavy suspension of spores of *H. sativum* in water. Enough of the suspension was added to cover the agar, and any excess was poured off by tipping the Petri dish. The seed to be tested was placed on the inoculated agar immediately, with 5 seeds on each dish. The plates were incubated at 24° C., and they were read about 48 hours later. At this time it was seen that the fungus had failed to grow in areas, roughly circular, around the treated seeds; indeed, there was very little growth on some of the plates even at a considerable distance from the seed. Untreated seeds, however, were completely surrounded and often overrun by the mycelium of the fungus. (Figure 1.)

## USE OF THE METHOD

When this method was used to test coverage by a seed-treating machine or other means, samples were taken at timed intervals as the seed was being treated. From each of these samples, about 20 seeds were taken at random and were sown on the inoculated agar. This showed the percentage of seeds receiving dust in any sample and indicated whether or not the dust was being applied evenly to the whole lot of seed.

The author has used this means to test various seed-treating machines and methods. The results of some of these tests, given in Table 1, showed considerable variation in the efficiency of certain machines and methods, and some fluctuation in the amount of dust applied to the seed.

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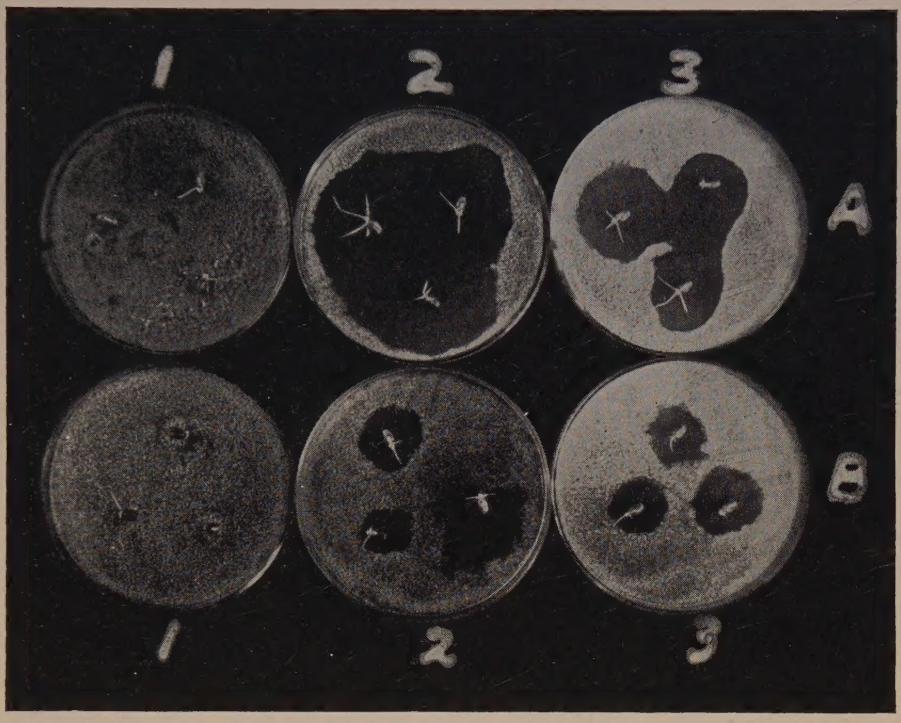


FIGURE 1.

TABLE 1.—SHOWING THE PERCENTAGE OF SEEDS DUSTED WITH CERESAN BY VARIOUS MACHINES AND BY THE HAND METHOD. THESE RESULTS WERE OBTAINED BY PLATING THE TREATED SEEDS ON INOCULATED AGAR

| Method | Sample | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Mean |
| | % | % | % | % | % | % | % | % | % | % | % |
| Machine No. 1 | 100 | 100 | 80 | 100 | 90 | 100 | 80 | 100 | 100 | 100 | 95 |
| Machine No. 2 | 100 | 100 | 100 | 90 | 100 | 100 | 100 | 100 | 100 | 100 | 99 |
| Machine No. 3 | 100 | 100 | 100 | 90 | 80 | 70 | 50 | 80 | 80 | 100 | 85 |
| Machine No. 4 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Machine No. 5 | 100 | 20 | 100 | 100 | 20 | 0 | 40 | 100 | 100 | 60 | 64 |
| Machine No. 6 | 55 | 100 | 100 | 95 | 95 | 64 | 15 | 100 | 100 | 60 | 79 |
| By hand: | | | | | | | | | | | |
| 2nd mix | 100 | 100 | 80 | 100 | 100 | 100 | 100 | 100 | 80 | 100 | 96 |
| 4th mix | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

Further tests to determine the inhibitive effect of other fungicides on *H. sativum* and other fungi, grown in the same manner on agar in Petri dishes, were conducted by Miss A. M. Dickey of the Plant Products Division, Saskatoon, while working temporarily at this laboratory. The results of these tests are given in Table 2.

TABLE 2.—SHOWING THE INHIBITIVE EFFECT OF VARIOUS DUST FUNGICIDES, CARRIED ON WHEAT KERNELS, ON THE GROWTH OF ELEVEN FUNGI FRESHLY PLANTED ON POTATO DEXTROSE AGAR AND INCUBATED AT 24° C.

| Fungus | Check | Fungicide | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Ceresan | Leytosan | Semesan | Spergon | Thiosan | Arasan | Copper carbonate |
| *Helminthosporium sativum* | 0 | +++ | ++ | ++ | + | +++ | +++ | 0 |
| *Fusarium culmorum* | 0 | ++ | ++ | + | + | ++ | – | 0 |
| *Coniothyrium* sp. | 0 | +++ | ++ | ++ | + | +++ | +++ | 0 |
| *Cephlaosporium* sp. | 0 | +++ | ++ | ++ | + | +++ | +++ | 0 |
| *Penicillium puberulum* | 0 | ++ | ++ | + | + | ++ | h | 0 |
| *P. lilacinum* | 0 | ++ | ++ | + | + | ++ | + | 0 |
| *Penicillium* sp. No. 100 | 0 | 0 | + | 0 | + | 0 | 0 | 0 |
| *Penicillium* sp. No. 551 | 0 | ++ | + | + | + | + | h | 0 |
| *Trichoderma* sp. No. 521 | 0 | ++ | 0 | + | 0 | + | 0 | 0 |
| *Trichoderma* sp. No. 541 | 0 | ++ | + | + | 0 | + | h | 0 |
| *Aspergillus flavus* | 0 | ++ | ++ | + | + | ++ | + | 0 |

Legend:
0 = no inhibition
\+ = slight inhibition
++ = moderate inhibition
+++ = complete inhibition
h = growth hindered but not prevented
– = no test.

It will be seen in Table 2 that inhibition of growth of several fungi, growing from a spore suspension newly placed on agar may be caused by several fungicides. Among these were three organic mercury dusts and three organic non-mercury dusts. All of the former class prevented germination and growth of most of the fungi. Of the latter class, thiosan had the greatest effect. Copper carbonate did not suppress any of the fungi. One species of *Penicillium*, isolated from wheat roots, resisted most of the fungicides.

## CONCLUSIONS

It was found by exploratory tests that this method was very sensitive and that very small amounts of Ceresan could be detected on wheat seed. It is reasonable to expect that the other fungicides could be detected in small quantities also. The positive nature and sensitivity of the test makes it reliable in determining the presence of fungicides and the coverage on a seed sample. Its non-specificity prevents its use to determine the nature of the fungicide. With certain modifications, such as the use of uniform glass beads to carry the dusts, this method possibly could be used in the evaluation of fungicides, preliminary to extensive field tests.

## SUMMARY

A biological test for the presence of fungicides on seeds is described. The basis of the test is the inhibition of growth of certain fungi on agar in the immediate neighborhood of treated seeds.

SOIL AND PLANT ANALYSIS. C. S. Piper, D.Sc. Interscience Publishers Inc., 215 Fourth Ave., New York 3, N.Y. 1944. $4.50.

This book on methods of soil and plant analysis is probably unique in that plant analysis is given a place in a text which deals so fully with physical and chemical analysis of soils.

As the author states, the methods outlined in the text have been fully tested at the Waite Agricultural Research Station, and furthermore a wide variety of soils has been used in checking the validity of the results by the different methods.

The book provides the laboratory worker with a most comprehensive discussion of almost every determination he is likely to encounter in the analysis of soil or plant material with the exception of "available" methods. In regard to the latter, the author feels that none of the many proposed methods has gained general acceptance and therefore is not included in the text.

The inclusion of a section on plant ash analysis in a text book dealing quite fully with analysis of the soil appears to be an excellent provision. Nearly every technician or investigator finds it necessary to carry out some form of ash analysis at one time or another. It is an undoubted convenience to have the methods of plant analysis gathered within the same cover as procedures for the analysis of soils.

In addition to considering methods adapted to the determination of the more common mineral elements in plant ash, attention is also given to the matter of determining trace elements.

All in all, Piper's *Soil and Plant Analysis* appears to be a timely and valuable contribution to the subject. Workers in this field should find this a useful text for reference and a convenient source of information on methods they may not have had occasion to become familiar with previously.

J. MITCHELL.

## ERRATUM

In the article entitled, "Topography and minimum temperature" by W. D. Albright and J. G. Stoker, November 1944 issue of *Scientific Agriculture* (Vol. 25, No. 3, p. 151), there is an error in Table 3, second column under No. V. The figure for the year 1938 should be 0.96 instead of 0.06.